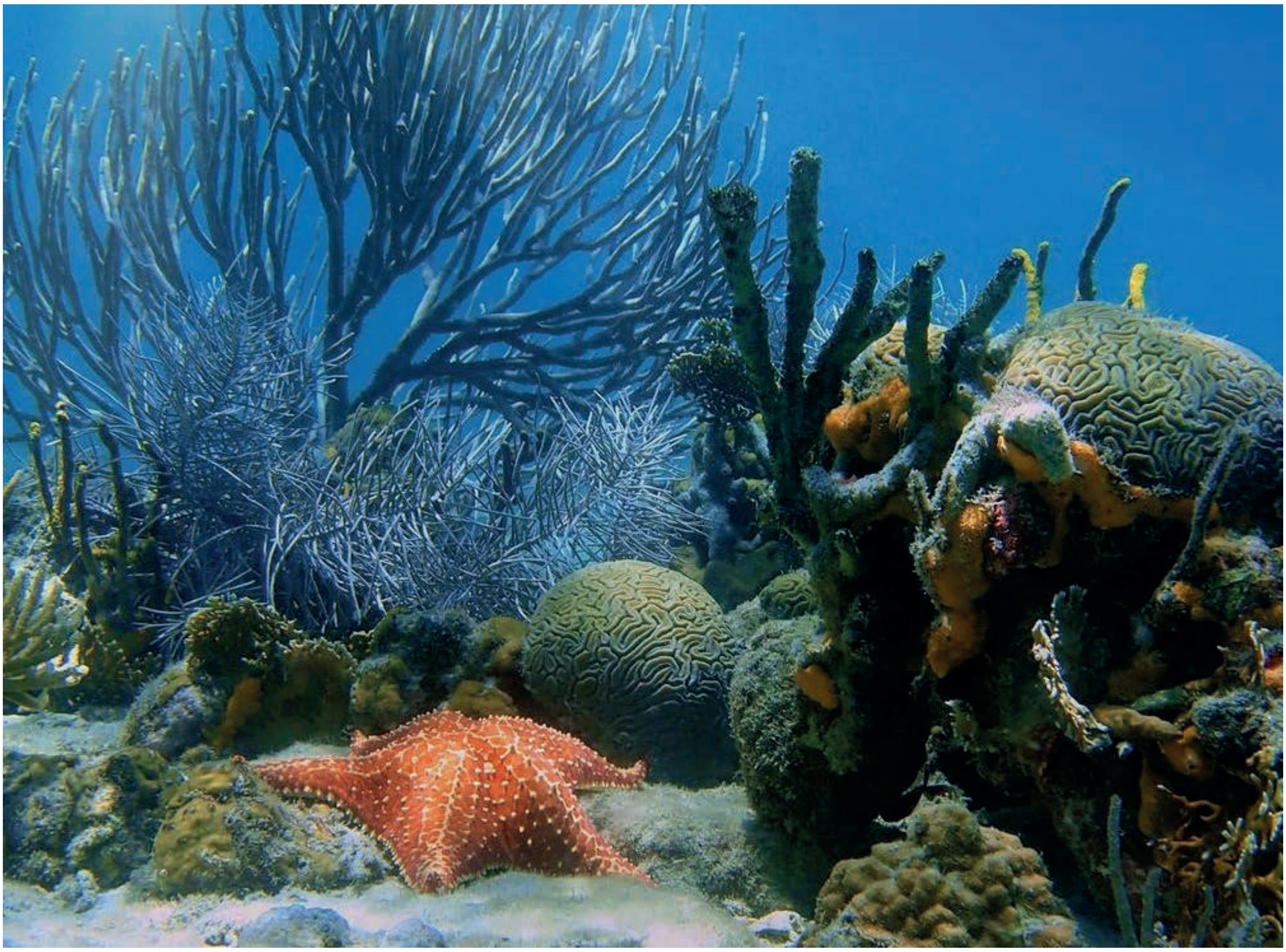
Tidal Range Developments: Considerations for the Historic Environment

Bill Cooper and Antony Firth

Discovery, Innovation and Science in the Historic Environment



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Tidal Range Developments: Consideration for the Historic Environment

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PREFACE

This report has been published at a time when the UK Government is still to offer a formal response to the Hendry Review or to confirm a power purchase agreement (also known as a Contract for Difference - CfD) for the Swansea Bay Tidal Lagoon, the prominent scheme generally regarded as the pathfinder project and catalyst for investment in further tidal range schemes. Decisions on both issues are likely to have major implications to the rate of progress of other tidal range projects, whether the decisions are favourable or not.

ACKNOWLEDGMENTS

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1. INTRODUCTION

The UK Government is expected to respond to the Hendry Review of tidal lagoons (Hendry, 2016) in the near future. The author of the review, Charles Hendry, was supportive of the strategic case for a tidal lagoon programme to deliver a cost-effective part of the UK's energy mix. If this case is accepted by UK Government, then the likelihood is the spawning of a new industry, most likely led by the pathfinder Swansea Bay Tidal Lagoon scheme. Clearly, the pace at which any such industry emerges will still depend on many factors, not least the commercial justification for each project.

Whilst the full extent of any programme is unknown, the potential sites for deployment of tidal range developments (including tidal lagoons, barrages and other tidal range technologies) are already quite well- established and described across several recent reports. Most sites considered to be commercially viable fall within two geographical regions provided with a suitably large tidal range; the Bristol Channel and the Eastern Irish Sea. For Historic England's interests, this means developments could affect southwest and northwest coasts of England and potentially over extensive areas through far-field effects on the tide which could lead to a potential loss of designated intertidal habitats. An extensive programme of tidal range development could also lead to an equally extensive programme of habitat compensation. Necessarily, areas affected by a development and any associated areas required for compensation would both need to be considered for implications to heritage assets. Arguably, compensations sites may need to be located well away from the effects of tidal range developments, potentially in estuaries on the east coast of England.

This research project provides Historic England with an up-to-date view of current interest in tidal range developments which may have implications across English Waters. The report should help engagement with project developers and with relevant Government departments, and their agencies, to ensure that the interests of the marine historic environment are addressed appropriately.

Tidal stream projects which are reliant on strong flows are not considered in this research.

1.1 Structure of the Research Report

Section 2 sets out the different types of tidal range developments and the typical elements involved in a project and discusses their scale, the zones they affect and key phases of the development process.

Section 3 of the research report outlines the main environmental criteria required to make a tidal range development feasible, given present technology options, and identifies the regions where the exploitable resource opportunities are most likely.

Section 4 provides a summary of known developer activity for these regions, focussing on projects which are identifiable in the public domain at the time of publication.

Section 5 considers the current marine policy and legislative framework relevant to tidal range developments, including the potentials implications of Britain exiting (BrExit) the European Union.

Section 6 reviews the types of heritage assets likely to be affected and the implications for the historic environment in different zones.

Section 7 draws together the main conclusions from the research project and provides various recommendations for Historic England to consider

2. TIDAL RANGE DEVELOPMENTS

2.1 Types of Tidal Range Developments

In this research project, tidal range developments are any type of scheme that relies upon the rise and fall of the tide, whether this is for power generation or other commercial reasons. This review has identified a variety of tidal range development types which are generally differentiated by their location and the amount of land used to form an impoundment. These differences also provide a basis for common nomenclature:

(a) Barrage

A barrage relies on the land boundary of an estuary with turbines located across the estuary where there is water of suitable depth and sufficiently wide to accommodate a turbine power house, but also with shallow and/or narrow margins to avoid long causeways or deep water closing walls. The resulting impounding basin is held in a natural formation. A large river will normally discharge into the rear of the impoundment.

(b) Shore-connected Lagoon

A lagoon which requires impounding walls to connect a power house in deeper water onto the adjacent coastline. A section of coastline is used to complete the impounding basin. Lagoons can be located on the open coast or within a large estuary, but they do not dam the water across an estuary in the way a barrage would. In some cases, small rivers may still discharge into the impoundment. Shore-connected lagoons are likely to contain large areas of intertidal within the impounding basin.

(c) Offshore Lagoon

A lagoon which does not connect to the land and remains a distance offshore. For a comparable scheme in similar depth and tidal range, the length of the impounding wall for an offshore lagoon would inherently be longer. Such a scheme would probably avoid areas of intertidal being included within the impounding basin and no small rivers would discharge into the basin either.

(d) Electric Bridge

Apart from barrages and lagoons, this review of developer activity has also identified **Electric Bridges**. Such schemes may have similar alignments to some barrage options and may therefore provide a viable alternative option to a barrage, in some cases. Electric bridges use free flowing venturi turbines rather than conventional low head bulb turbines and do not impound water like a lagoon or barrage to create a low tidal head over the scale of an impounding basin. Although occasionally classified as a type of tidal stream device, their siting is not necessarily dependent on the same criteria as a more conventional open water tidal stream device which requires a fast flow to turn an impeller since the venturi turbine creates a pressure difference to drive the turbine. Typical tidal stream arrays are outside of the scope of this review.

(e) Hybrid Infrastructure

As well as these different forms of tidal range development, a further point of note is that electricity generation may be only one facet of some tidal range developments. Hendry refers to **Hybrid Infrastructure** which has multiple, major benefits, including – for example – flood protection, recreation, local regeneration and tourism. In some cases, these other benefits of tidal range development may be of greater importance than electricity generation. From a historic environment perspective, the attention being directed to regeneration, recreation and tourism might present an important opportunity for heritage to add to overall benefits; but equally, the existing contribution of heritage to local economies and communities could be adversely affected by impacts from insensitive tidal range development on neighbouring heritage assets.

2.2 Scales of Tidal Range Development

There does not yet appear to be any consensus for referring to the scale of a tidal range developments apart from the amount of installed capacity, in units of Mega Watts (MW). A rough categorisation can be inferred from the Hendry Review, by reference to the threshold in the NPS for Renewable Energy Infrastructure (DECC, 2011) and other sources:

500 MW+	Large/Very Large
100 – 500 MW	'Pathfinder'; potential threshold for Nationally Significant Infrastructure Projects
30 - 100 MW	Intermediate; below threshold for NSIPs
Below 30 MW	Small (Community-scale)

Hendry makes a distinction between the usefulness of a 'relatively small' (that is less than 500 MW) pathfinder project and the programme of larger developments that follows. He proposes that the programme of larger developments be subject to a specific National Policy Statement (NPS – discussed below) but that the pathfinder should be separate from this programme. He also recommends that 'smaller scale' lagoons and barrages continue to be developed and constructed while any programme of larger developments is being considered (Hendry, 2016).

What should be borne in mind is that although the Swansea Bay Tidal Lagoon is envisaged as a 'smaller scale' pathfinder project, the development itself is very large. While Hendry envisages that a programme of 'large' developments may require time to emerge, schemes which are themselves large may come forward in the meantime both above and below the possible threshold of NSIPs. To this can be added the possibility of the emergence of community-scale schemes of 30 MW and less, which could still have significant impacts on the historic environment if they are sited inappropriately.

2.3 Components of a Tidal Range Development

There are common components to most types of tidal range developments, such as:

- Turbines grouped together in a power house (turbine house), generally requiring placement in deeper water.
- Closing walls to impound a large basin of water, with barrages requiring the shortest walls while utilising the adjacent estuary shorelines. Lagoons will either utilise part of the adjacent coastline, and extend out to sea, or require a full impounding wall utilising no coastline if they are located fully offshore. Developers will favour shallower water for closing walls to avoid excessive cost. A long impounding wall in an area of high tidal range will redefine the landscape, especially when exposed during low water periods. The structure will also most likely attract high levels of marine growth.
- Sluices to provide efficient filling of the basin.
- Lock gates to provide access into the basin. The scale of any lock gate will depend on the need to provide access to large commercial vessels (a requirement most likely for barrages across large estuaries), or other craft such as dredgers if the depths in the basin needs to be maintained from high rates of siltation (a likely requirement for most lagoons).
- Export cables to connect the power generated to the grid. An offshore lagoon will inevitably need to cross the seabed to reach landfall, and then onto the grid connection. Shore-connected schemes have the option of routing the export cable in the alignment of the closing wall without a need for any seabed installation.

All these elements will be the subject of comprehensive site investigations, detailed design, construction planning and environmental impact assessment. The design process will also seek to optimise these elements and how they function for power production and to control costs. During the design process many design iterations can also be expected from conceptual to final design. For illustration, the Swansea Bay Tidal Lagoon went through more than a dozen layout iterations.

Once the construction and operating phases have been evaluated for environmental impact, and mitigation measures have been considered, then residual impacts may need suitable compensatory measures. For example, a scheme which is demonstrated to lead to a net loss of intertidal habitat will need to offer suitable compensatory measures to offset such a loss. Accordingly, the full project will also need to include the compensation requirements as part of the application for consent.

2.4 Zones affected by Tidal Range Developments

The effect of tidal range developments on the environment, including the historic environment, varies considerably across the overall footprint of the scheme, as well as also beyond the footprint. Consequently, splitting a tidal range development into a series of zones may be helpful. Effects in each of these zones will differ according to the phase of development, especially between the construction and operational phases. In some zones, effects on the historic environment are greatest in the construction phase; in other zones the operational phase may result in the most significant effects.

The zones identified for the purposes of this research are as follows:

- Construction footprint
- In proximity to power houses and sluices
- Within the impoundment
- Beyond Impoundment

(a) Construction footprint

The construction footprint includes the area directly impacted (on land and out at sea) by the construction of impoundment walls, turbine houses, sluices, locks and other associated infrastructure. Dredging for borrow pits, to increase overall volume, as general levelling or for other enhancement of the scheme is best regarded as part of the construction footprint even if this activity is not directly related to any structures and their foundations. As an example, areas of proposed dredging within the Swansea Bay Tidal Lagoon impoundment are shown on Figure 1.

This footprint also includes any temporary works, such as; coffer dams, access roads, compounds and routes and areas where physical impacts occur whilst completing marine works.

(b) In proximity to the turbine house and sluices

This is envisaged to be the near-field area adjacent to turbines and sluices, both inside and outside of the impoundment, where water becomes focused with much higher velocities than in the baseline, most likely extending over distances of hundreds of metres. The likelihood is that construction and/or operation will cause significant changes to bed levels by altering water flow and sedimentation; the seabed in this area may need to be armoured to avoid local scouring.

(c) Within the impoundment

This is envisaged to be the area away from any sluices or turbines. No construction works for new engineering structures are expected to take place in this area and bed levels remain predominantly unchanged, notwithstanding the previous comment about potential dredging in some cases.

Fig 1 Proposed dredging plan within Swansea Bay Tidal Lagoon impoundment (Tidal Lagoon Swansea Bay, 2014).

Impounded waters will behave more calmly than prior to the development because the free passage of water on flood and ebb tides will now be excluded. If suspended sediments are brought through turbines and sluices during the impoundment filling cycle, then siltation may become an issue in this zone and maintenance dredging and disposal of spoil may be required in some cases. If the impoundment encloses areas of intertidal, then the rise and fall of water levels will become governed by the operating cycle. The likely changes are a reduction in tidal range due to a lower high tide and a higher low tide.

A further affect in this zone may occur as a result of a much-reduced fetch by the impoundment walls creating a degree of shelter from local winds, the consequence being a reduction in wave energy that may have been present prior to development. For impoundments which still include some shallow intertidal areas then the dissipation of wave energy on the shoreline will also reduce and these zones may become prone to deposition and tend towards a muddier profile if such sediment is available.

(d) Beyond the impoundment

This area is envisaged to go beyond the immediate area of the impoundment (near-field) and extend for several tens of kilometres across the far-field region where there is still likely to be detectable changes in water level, especially in the intertidal zone.

The potential remains for far-field impacts to overlap between projects within the same geographic region, with a consequence of creating a larger cumulative impact. This type of interaction may also change the potential tidal resource available within a region.

The cumulative impact between some regions is also a likelihood, but this would depend on the overall scale of development.

The zone beyond the impoundment also encompass the area where there may be effects on the setting of heritage assets, predominantly from visual impacts.

2.5 Phases of Tidal Range Development

The following four phases can be anticipated for tidal range development and are important in contemplating the kinds of effect that may occur on the marine historic environment.

2.5.1. Pre-Construction

The pre-construction phase includes the entire period from preparation of initial proposals through to the start of physical works on site. This phase may span many years to accommodate periods of design, development of the commercial case and securing investment, consenting, environmental assessment and meeting any necessary pre-construction consent conditions. Although this all occurs before major works commence, the likelihood is that a range of non-intrusive and non-intrusive site investigations will need to take place. Intrusive site investigations may themselves have impacts on the historic environment; whilst both intrusive and non-intrusive investigations may also present an important source of new data to help assess potential impacts on the historic environment.

2.5.2. Construction

Construction related affects will depend on the method of installation. Arguably, they represent the highest level of disturbance in the shortest period.

The area of seabed where structures are to be placed may need extensive preparation, including dredging, levelling and armouring. Installation of the turbine house, and associated seabed armouring, may also require extensive cofferdams over a much larger footprint than the final structures.

2.5.3. Operational

The three zones considered for operational effects in Section 2.4 (b), (c) and (d) would persist over a notional period of up to 120 years.

2.5.4. Decommissioning

At the end of the operational period the scheme's solid structures are likely to have become part of the accepted landscape. Their removal could create large amounts of disturbance and further environmental impacts. Indeed, Hendry has recommended that the Government should accept that once built, the sea wall of a tidal lagoon should be considered as permanent in relation to decommissioning (Hendry, 2016).

Some of the mechanical and electrical components may be recovered during decommissioning if they hold residual value. If the turbines and sluices are removed then there will be associated changes in flows in and out of the impoundment, modifying the water level profile again and altering siltation rates. Levels within the impoundment could then rapidly reduce if maintenance dredging of the basin also ceases.

The evaluation of the effects of tidal range developments for consenting, especially in terms of their landscape setting, should therefore consider a scenario of becoming a permanent feature when major structures are excluded from decommissioning.

3. ENVIRONMENTAL CRITERIA FOR TIDAL RANGE DEVELOPMENTS

3.1 Site Selection

An overview of the site selection process for a tidal range development is offered as a context for known developer activity, but also to highlight areas where future interests may still arise.

Site selection is led by knowledge of the resource potential, which for a tidal range development relates to locations where the rise and fall of the tide is sufficient to enable a suitable head of water to be created for a suitable volume of water which can be stored and released for power generation.

The storage of water requires a method of impoundment which either makes use of natural land boundaries, such as estuaries, or creates new impoundment walls in open water. The former would be recognised as a tidal barrage option whereas the latter is regarded as a tidal lagoon.

Shallow depths are preferred for impoundment walls to avoid excessive cost of construction, but deeper water is required for placement of turbines.

All structures placed on the seabed also need stable ground conditions to avoid settlement issues and/or large-scale erosion.

Finally, power generation needs to be supplied to a suitable connection on the electricity grid which may involve long sections of both offshore and onshore cables along suitable routes.

Accordingly, the primary criteria for site selection are:

- Tidal resource
- Water depth
- Ground conditions

Other criteria may challenge site selection and be considered as constraints, including environmental and socio-economic impacts. These constraints may only become known once a project advances into feasibility studies and preliminary site investigations.

3.2 Tidal Resource

The resource potential for tidal range developments can be split into three hierarchical levels, adapted from *Tidal Power in the UK* (Sustainable Development Commission, 2007):

i **Theoretical Resource** – the full resource contained across an entire area before any other considerations are made.

ii **Technical Resource** - the proportion of the Theoretical Resource that can be exploited using presently available technology. As technologies advance, further areas of the Theoretical Resource may become exploitable.

iii **Practical Resource** - the proportion of the Technical Resource which can be exploited after consideration of external constraints, for example grid accessibility, competing uses such as shipping, environmental sensitivities, and so forth.

3.2.1. Theoretical Resource

The UK Atlas of Marine Renewable Energy (BERR, 2008) illustrates the Theoretical Resource for tidal range across the UK Continental Shelf using maps of mean spring and mean neap tidal range. The data supporting these maps was derived from a continental shelf scale tidal model (CSX) operated by the National Oceanographic Laboratory, Liverpool.

The general detail provided by the model is one nautical mile which means many small and medium sized estuaries are not fully resolved, consequently such sites with a suitable tidal range do not appear when the maps are used to identify areas of Technical Resource.

Referring to the Atlas for mean spring tides (Figure 2) identifies coastal regions with relatively higher and lower tidal range. There are four main regions around the English coast which experience relatively higher tidal ranges:

i Eastern Irish Sea (North West, and North Wales and Liverpool Bay)

ii Bristol Channel (Severn Estuary)

iii Eastern English Channel (South East)

iv The Wash (East Coast)

The alternative names offered in parenthesis are those applied in the Hendry Review (Hendry, 2016).

A further comment is offered here regarding the energy that can be stored within an impounding basin to provide context on developer's likely interests in specific sites. The energy stored in an impoundment can be determined by the mass of water held above the water level outside of the impoundment:

potential energy = mass x gravity x head.

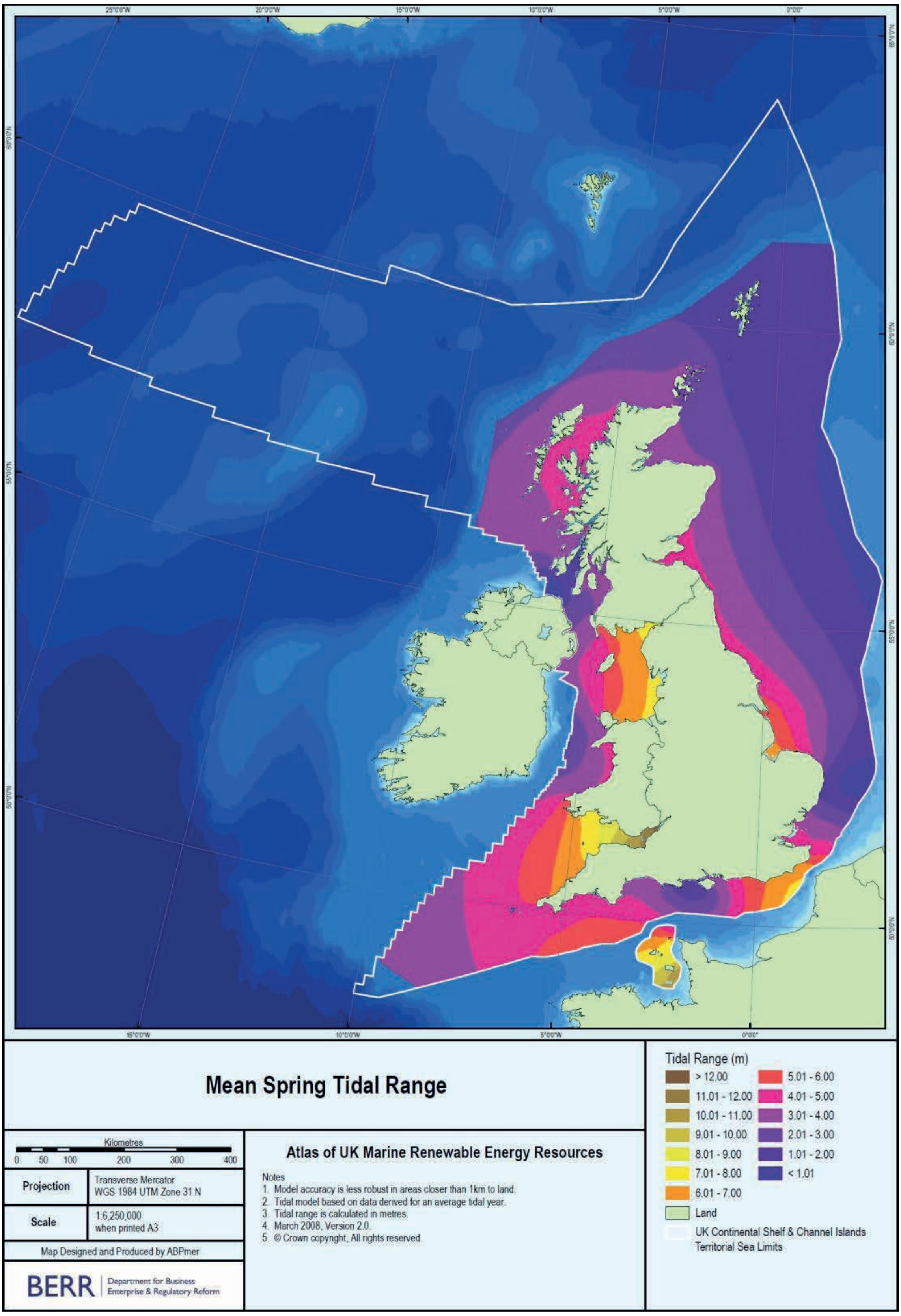

Fig 2 Mean Spring Tidal Range across UKCS (BERR, 2008).

The mass is given by the volume of water and water density, where A is the area of the impoundment, H is the height above the water level outside and ρ is the density of the sea water, that is mass is determined as;

$$A\,H\,\rho$$

The head is the distance between the centre of gravity of the water body held above the water level outside of the impoundment;

$$H/2$$

Therefore, the potential energy stored in the impounding basin is given as:

$$E = A\,H\,\rho\,H/2$$

which can also be expressed as:

$$E = A\,H2\,\rho/2$$

The maximum potential energy is when H is equivalent to the difference in water levels between high water to low water, that is the full tidal range. In some situations, pumping extra water in or out of the impoundment can be included to increase the head further. Tidal power is generated when this energy can be converted over a tidal cycle through a series of tidal turbines.

Since the power available per unit area of impoundment increases by the square of the operating head (H), this makes the higher tidal range sites economically preferable for development as they will generate greater outputs for equivalent areas of impoundment. Therefore, most developers of commercial scale schemes tend to be exploring options at locations with much higher mean tidal ranges rather than sites which appear from the lower limit of economic viability.

3.2.2. Technical Resource

The Technical Resource for tidal range developments can be demonstrated by existing strategic studies such as recent publications from The Crown Estate (2012) and DECC (2016).

(a) Tidal range

For conventional power generation from tidal range a scheme relies on creating a 'low head' difference between water inside and outside of an impoundment. The tidal head is created by artificially delaying the exchange of water into (flood generation) and/or out of (ebb generation) the impoundment basin. For reference, the hydraulic head for power generation in hydroelectric schemes, such as dams, can be classified as low, medium or high, but there is no universal definition for threshold values to differentiate between these terms. The technical criteria for schemes which do not rely on creating a 'low head' are not considered.

The generally accepted minimum threshold for economic viability for a Technical Resource are sites where the mean tidal range is better than 4m (for example The Crown Estate (2012). Tidal conditions which experience a rise and fall greater than 4m are also referred to as macro-tidal. Some more recent strategic studies have used a threshold of greater than 5m, for example DECC (2016). The outcome from either study indicates largely similar locations of Technical Resource when other criteria are included.

For reference, mean tidal range (MTR) is defined as the difference between the mean of all high waters and all low waters over a period of one year (or several years). MTR will show variability between years due to long period (18.6 year) lunar nodal variations, as well as secular trends due to sea level rise. Importantly, this definition is not exactly equal to the average of mean spring and mean neap tidal ranges, although the latter is commonly used to obtain a basic estimate.

Although MTR > 4m may introduce a minimum condition to achieve economic viability, the main areas of interest are likely to be where the economic gains are greater due to much larger MTR (see Section 3).

(b) Tidal range - estuaries

Whilst Figure 2 is useful in indicating four coastal regions providing relatively high tidal range, there are likely to be additional sites where the MTR in estuaries also exceed 4m. Estuaries situated within one of the four coastal regions will most likely amplify the already high tidal range at the open coast. Estuaries elsewhere may still provide a Technical Resource if they contain sufficient areas to impound their higher tidal ranges.

For example, whilst the tidal range in the Outer Thames may be moderate (MTR estimated as < 4m at Shivering Sands), the amplification within the estuary leads to a higher range (MTR is likely to be greater than 5m upstream of Tilbury) (PLA, 2017). However, not all the estuary will be suitable as the tidal amplification effect will reach a maximum position after which dampening effects due to shallowing and further narrowing effects against the landward slope and competing river flows become dominant. The tidal range in the Thames Estuary increases upstream to Tower Bridge with an estimated MTR of 5.5m, but reduces thereafter.

A similar situation occurs in the Humber Estuary. At the outer estuary, the estimate for MTR at Spurn Head is around 4.4m, increasing upstream to Hull with MTR > 5m, but decreasing thereafter.

(c) Water depth

An associated criterion for the Technical Resource is the ability of a tidal range development to impound a sufficient volume of water in a cost-effective way, which may involve a combination of constructing impoundment walls (preferably in shallower water) and placement of multiple turbines in deep water. The deep water requirement for the turbine housing is to ensure that the top of the rotor diameter (D) always remains sufficiently submerged, especially at lowest astronomical tide (LAT) when the maximum head is developed, to avoid cavitation issues.

Cavitation is a phenomenon that can occur due to a rapid drop in pressure when flows accelerate towards the turbine, resulting in cavities (bubbles) forming. When cavities collapse due to any slight pressure rise they create localised high-pressure zones which can damage turbine blades, leading to cavitation corrosion.

The turbine runner diameter for a tidal range development depends on the manufacturer and technology options, with developers and scheme designers choosing between a few higher rated turbines with larger rotor diameters or a larger number of lower rated turbines, depending on site conditions, to achieve the full target installed capacity for their respective development.

Presently, a bulb turbine with a 9m runner diameter is generally regarded as the largest option likely to be commercially available in the near future. For reference, the Cardiff-Weston alignment for a Severn Tidal Barrage was based 216 turbines each rated at 40 MW (total installed capacity of 8.64 GW) with a runner diameter of 9m (Sustainable Development Commission, 2007).

To accommodate the largest turbines, and to avoid cavitation effects, a minimum depth (that is depth below lowest astronomical tide (LAT) to the lowest part of the rotor of around 2.25 times the diameter is required for a generic bulb turbine (Raabe, 1985). For a 9m turbine diameter this equates to around 20.25m below LAT. For reference, recent strategic assessments for tidal range developments have applied a criterion of 25m (or less) below mean sea level (The Crown Estate, 2012 and DECC, 2016). If local water depths are a limiting condition at the preferred location, then additional excavation or dredging may be required to achieve the design levels.

Excavation beyond the design depth of the turbine will also be required to enable a level seabed for installation of the turbine house foundations. In some cases, this excavation may extend well beyond the immediate location of any turbine house and on both the seaward side and within the impoundment.

Figure 3 provides an example of a bulb turbine from the operational tidal barrage at La Rance (de Laleu, 2009). In this case, the runner diameter is 5.35m, with the base of the turbine house at 10.05 m below LAT and an excavated foundation depth of at least 12.9m below LAT.

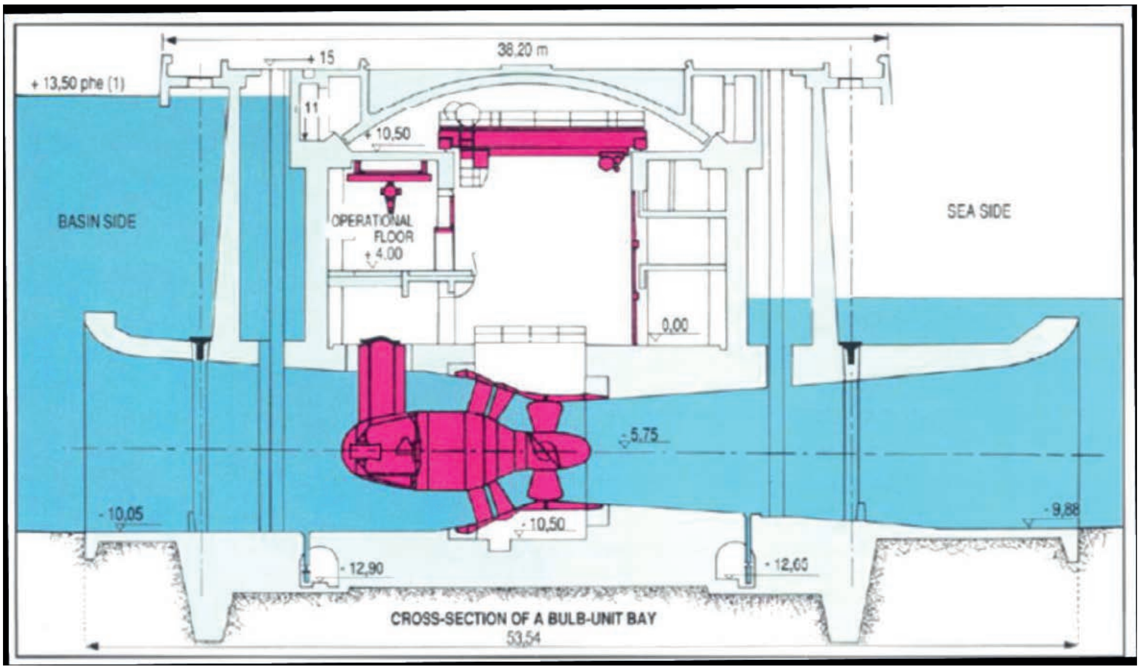

Fig 3 Example of a bulb turbine, La Rance, from Laleu (2009). [levels quoted relative to LAT]

To summarise, the Technical Resource for presently available tidal range technology is considered here to be at sites where the mean tidal range is at least 4m and where sufficient depths are available for turbine housings, which is likely to require depths of around 20m LAT for the largest turbine runner diameters (up to 9m), or shallower depths when the scale of the turbine runner diameter is smaller (less than 9m). The area required for any impoundment (barrage or lagoon) depends on the level of installed capacity being considered for power generation but is expected to be several square kilometres.

3.2.3. Practical Resource

The Practical Resource will become a consideration for developers as individual schemes move from site selection towards project feasibility and preliminary design. At this stage, more detailed data and site information will need to be obtained to help identify and confirm potential constraints on development. Typically, there may be several design iterations to both optimise scheme performance and minimise/mitigate potential issues as this data becomes available. If there remain major gaps or residual uncertainties in technical understanding of ground conditions, then site investigations are likely.

A full understanding of potential issues will only develop through early engagement with stakeholders and statutory consultees, a process which should always be encouraged at the earliest opportunity to help frame technical studies required to support a subsequent application for consent.

Where a scheme may lead to direct and/or indirect losses to intertidal areas then the issue of compensatory habitats needs to be considered. The availability of sufficient suitable compensatory habitats may also become a project constraint.

To date, tidal range developments, such as the Severn Tidal Barrage and the Swansea Bay Tidal Lagoon, have tended to be considered as individual, unique projects with site-specific issues. The lack of directly applicable case evidence from other developments and the lack of any specific guidance for developers, regulators and technical advisors may also be regarded as a constraint to early 'first of a kind' developments.

4. SITES OF PRESENT INTEREST

Details from operating and consented schemes are initially summarised in Section 4.1 to offer an indication of the likely scales involved for similar tidal range developments. Section 4.2 comments on the status of the Severn Barrage interest, with Section 4.3 providing a brief review of schemes known of in the public domain for each of the four geographic regions previously identified in Section 3.2.1.

4.1 Operating and Consented Schemes

There are presently no consented or operating tidal range developments in English Waters, however, for context a summary key dimensional features of operating barrages from La Rance, France and Shiwa, South Korea is offered, alongside the consented Swansea Bay Tidal Lagoon (Table 1). Other smaller operating barrages in operation around the world are not considered here.

Table 1 Summary of scales and dimensions for operating barrage schemes at La Rance, France and Shiwa, Korea, plus the consented Swansea Bay Tidal Lagoon.

Site	**La Rance**	**Shiwa**	**Swansea Bay**
Country	France	Korea	Wales
Type	Barrage (estuary)	Barrage (bay)	Lagoon (shore connected)
Installed Capacity (MW)	240	254	320
Turbine number	24	10	16
Turbine Capacity (MW)	10	25.4	20
Turbine runner diameter (m)	5.35	7.5	7.2
Depth at turbines (m below LAT)	10.5	15.36	14.35
Depth at turbines (m below MSL)	17.0	20.98	19.35
Length of power house (m)	332.5	150	410 (max) Including sluices
Width of power house (m)	53.54	61.1	67.5
Length of impounding wall (km)	0.75	12.5	9.5
Area of impounded water (km2)	22	42.4	11.5
Mean tidal range (m)	8.2	5.57	6.58
Maximum tidal range (m)	13.5	11.0	10.5
Year of operation	1967	2011	Consented in 2015
Reference	de Laleu (2009)	Young, Kyeong, and Byung	TLP

The schemes presented in Table 1 suggest that water depths of around 14 to 16m (below LAT) need to be available to install a large power house comprising multiple turbines with runner diameters of around 7m. Such a facility is likely to be 300 to 400m in length. Larger turbine runner diameters (*c* 9m) for larger capacity turbines would probably require greater depths in the order of 20m (below LAT).

4.2 Severn Barrage

For the present study, the possibility of a Severn tidal barrage option is excluded. This is in line with the UK Government's decision from a study reporting in 2010 that concluded:

> *'In the light of the findings of the feasibility study the Government does not see a strategic case to bring forward a Severn tidal power project in the immediate term.'* (DECC, 2010).

Despite this position, Hafren Power was established in 2010 to promote a scheme called Corlan Hafren. In 2013, the House of Commons Energy and Climate Change Committee examined their proposal and concluded the case for Government support was unproven, citing insufficient evidence. However, the Committee also suggested that Government should remain open to considering any marine project which is able to comply with the requirements of relevant EU and UK legislation – including a potential barrage scheme (House of Commons Energy and Climate Change Committee, 2013). Hafren Power is presently listed as a dormant company and no other known interests are pursuing a Severn Barrage at this time.

4.3 Regional Interests

A review of known developer activity in each of the four areas indicating a good Theoretical Resource is provided. Schemes located adjacent to English territorial waters are included because some environmental effects may translate across territorial boundaries, as well some of the infrastructure (for example export cables) being installed in English waters. In addition, where new compensatory habitats are required for any net loss then consideration may be given to sites well beyond the immediate footprint of the development. Maps and illustrations are included where such information is publicly available.

4.3.1. Eastern Irish Sea

For this research project, the Eastern Irish Sea Region extends from the Scottish border within the Solway Firth (the UK estuary with the second highest tidal range), down the Cumbria Coast and across Liverpool Bay to the Welsh border in the Dee Estuary. Schemes being considered in Scottish and Welsh Waters which may still have a bearing on English Waters are included in this review.

(a) Solway Lagoon (Scotland)

A company called Ullman Offshore Lagoon (Solway) Ltd became incorporated in May 2016 (with the majority shareholder being Tidal Electric Ltd). The company appears to be undertaking a feasibility study to identify a preferred site to develop a 200 MW (20 x 10 MW turbines) tidal lagoon in the Solway Firth, Scottish Waters. This lagoon design is likely to be un-connected to the shore and require a seawall length of between 19 to 21km to create a fully offshore impoundment. Limited details are presently available.

Although this site is likely to be fully within Scottish Waters, there may still be some construction and operational impacts which translate across into English Waters, such as sediment plumes during construction, changes in mobile sandbanks and channels, moderate reductions in tidal range, and so forth.

www.tidalelectric.com

(b) Solway Energy Gateway (Scotland – England)

Project commenced in 2006 following re-discovery of a barrage proposal developed in 1966 for the site which originally proposed to impound water in a reservoir for water supply (Babtie Saw and Morton, 1966), Figure 4. In 2009, a study examined various tidal power options (barrages and lagoons) in the Solway Firth (Solway Energy Gateway, 2009). This work confirmed the suitability of the proposed site located at the alignment of a former

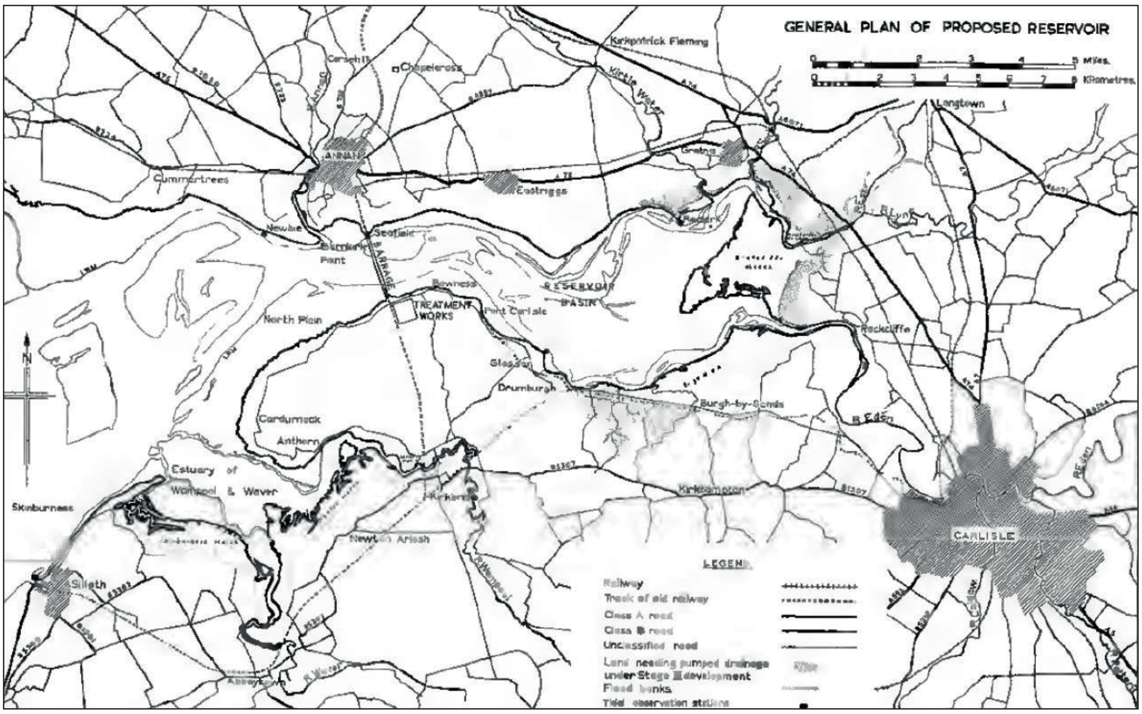

Fig 4 Alignment of Inner Firth, Solway impounding barrage and reservoir basin (from Babtie Shaw and Morton, 1966).

railway bridge between Bowness-on-Solway, Cumbria with Seafield, Annan, Scotland, a crossing of around 1.6km in the inner firth. The conservatively estimated 100 MW scheme is based on bi-directional (in-development) Venturi Enhanced Turbine Technology (VETT) with no requirement to impound water like a barrage, however, the present design would still appear to constrain the tidal channel with extended causeways to funnel the fast flows through an 0.8 to 1.0km gap. The project is presently pursuing funding to move things forwards. The project is partly within the Frontiers of the Roman Empire (Hadrian's Wall) World Heritage Site (WHS) (www.historicengland.org.uk/listing/the-list/list- entry/1000098).

MTR at the site (Newbie) is estimated at 5.8m.

www.solwayenergygateway.co.uk

(c) West Cumbria (England)

A potential lagoon being considered by Tidal Lagoon Power between Workington to Dubmill Point, West Cumbria, on the English Side of the Solway. The provisional design information suggests a 22.4km wall impounding an area of 92.1sq km for power generation from 90 turbines with an installed capacity of 2,200 MW. The project remains at the feasibility phase at this time with the developer giving priority to Cardiff and Newport lagoons. This project has recognised an important association with the milefortlet at Dubmill Point, which is a scheduled monument (www.historicengland.org.uk/listing/the-list/list-entry/1014803) and is partly within the Frontiers of the Roman Empire WHS (www.historicengland.org.uk/listing/the- list/list-entry/1000098).

MTR is estimated at 5.6m.

www.tidallagoonpower.com/projects/west-cumbria/

(d) Duddon Estuary (England)

In 2010, a study commissioned by Britain's Energy Coast explored tidal power generating options for the Duddon (Parsons Brinkerhoff, 2010). Tidal barrages, fences, reefs and other innovative technologies were all considered. The study concluded that a 160 MW tidal barrage at the mouth of the estuary (Figure 5) from Haverigg to Sandscale Haws (Option B2) is technically feasible and could be constructed by 2020 (at the earliest), however, progress in such a scheme would remain dependent on many commercial, environmental and regional considerations. This scheme would now seem to be part of the Northern Tidal Power Gateways initiative.

MTR of Duddon Estuary (Duddon Bar) is estimated as 6.5m.

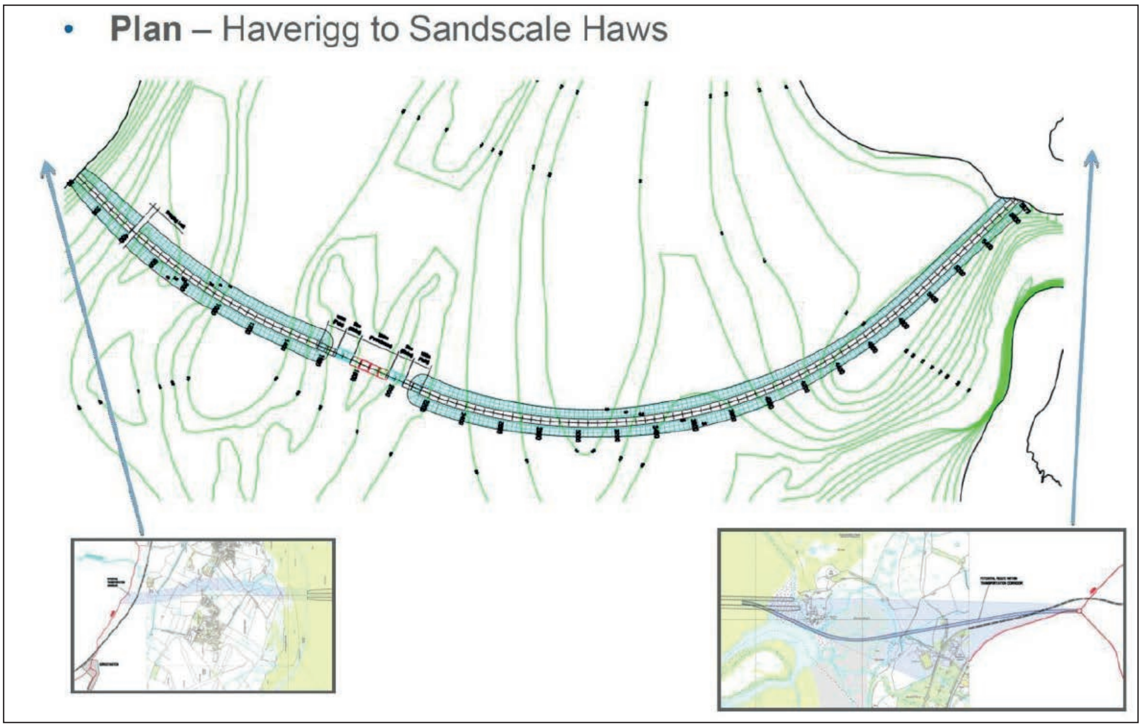

Fig 5 Proposed alignment of the Duddon Barrage (from Parsons Brinkerhoff, 2010).

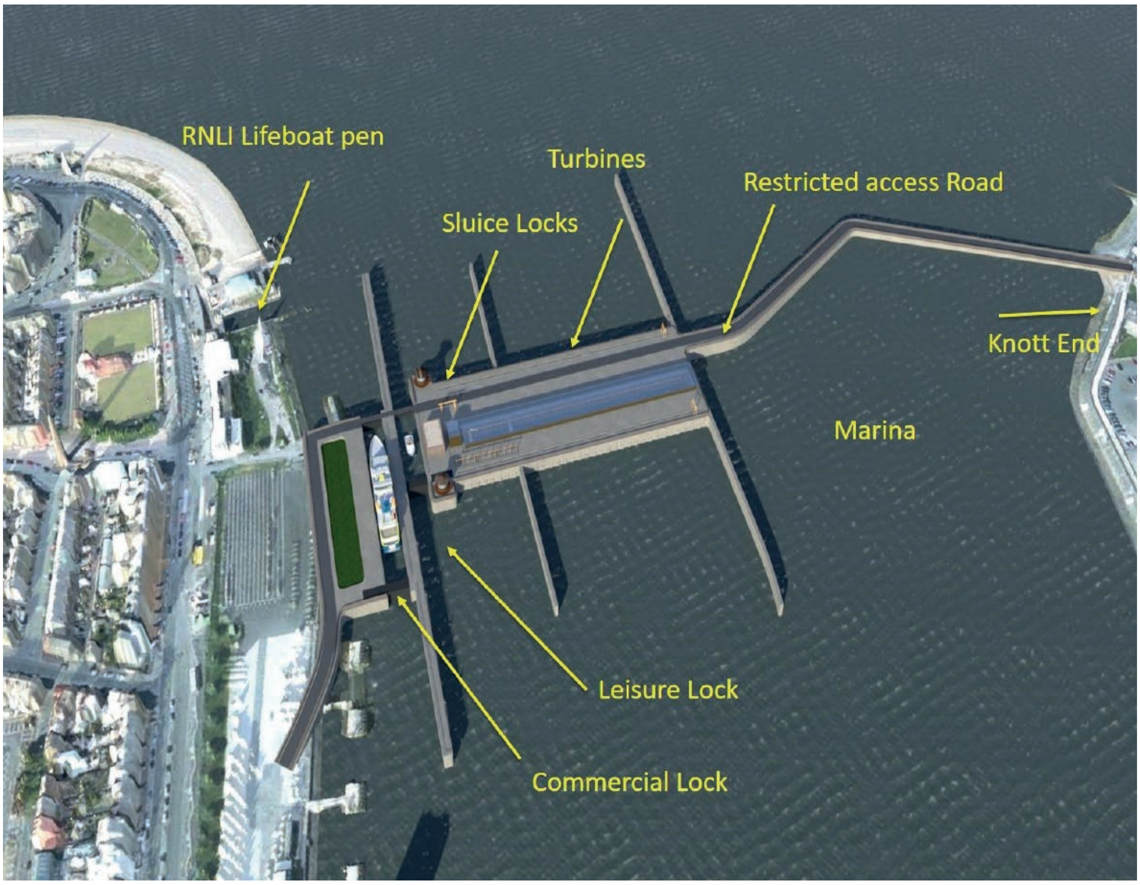

Fig 6 The Wyre Tidal Gateway (image from www.naturalenergywyre.co.uk/).

(e) Wyre (England)

There are two separate proposals at the same location between Fleetwood and Knott End where the river is around 480m wide: The Wyre Tidal Gateway and the Electric Bridge.

The estimated MTR of the Wyre is 6.6m.

The Wyre Tidal Gateway, a scheme now being co-developed between Natural Energy Wyre Ltd (NEW) and Atlantis Resources Ltd. This scheme also features as part of the larger 'Energy Coast' initiative. The barrage scheme shown In Figure 6 is based on 10m wide and 370m long structure with an installed capacity of 160 MW (8 turbines of 20 MW, each with a diameter of 8.2m), impounding an area of 5.8sq km. The project appears to be at concept design stage with an expected timeline to be operational by 2023.

www.naturalenergywyre.co.uk

Electric Bridge, a scheme being promoted by Wyre Tidal Energy Ltd as an 'Electric Bridge' (classified as a tidal stream device) with no requirement to impound the tide, unlike a conventional barrage. This project uses the same alignment across the river as the Wyre Tidal Gateway. This scheme is considered to have less environmental impact on the intertidal habitat (estimated to be around a 10 per cent loss of mud banks) and less risk to fish, but also an energy yield of about 60 per cent of a barrage. Gates will be operated at high and low water to develop a pressure head for venturi turbines (Venturi Enhanced Turbine Technology, VETT). This is the same technology proposed for the Solway Energy Gateway. The project is hoping to commission a pre-feasibility study soon.

www.wyretidalenergy.com

(f) Mersey Barrage (England)

In 2011, Peel Energy undertook a feasibility study of options for tidal power generation in the Mersey. The study identified a preferred scheme as a barrage across the river in the region of New Ferry (Wirral) to Dingle (Liverpool); Band A (Figure 7). The barrage option allowed for a potential installed capacity of up to 700 MW (28 x 25 MW turbines with a runner diameter of 8m) with a maximum energy yield in ebb only operation (Peel Energy, 2011). The feasibility study recognised there would be potential for impacts on the Liverpool Maritime Mercantile City WHS (www.historicengland.org.uk/listing/the-list/list-entry/1000104).

Peel Energy has stated they are not progressing the scheme at this time until there is further confidence in the financial and regulatory framework for tidal power. This study appears separate to the NWE2 initiative but was also part funded by Northwest Regional Development Agency (NWRDA).

At the end of 2017, funding was allocated by Liverpool City Region to Mersey Tidal Commission to reconsider the business case for the barrage and look at more detailed options and technical solutions. The production of an outline business case is expected to be completed by March 2018 (www.tidalenergytoday.com/2018/02/08/liverpools-mersey-tidal-scheme-granted-initial-funding/).

The estimated MTR of the Mersey (Liverpool) is 6.45m.

www.merseytidalpower.co.uk

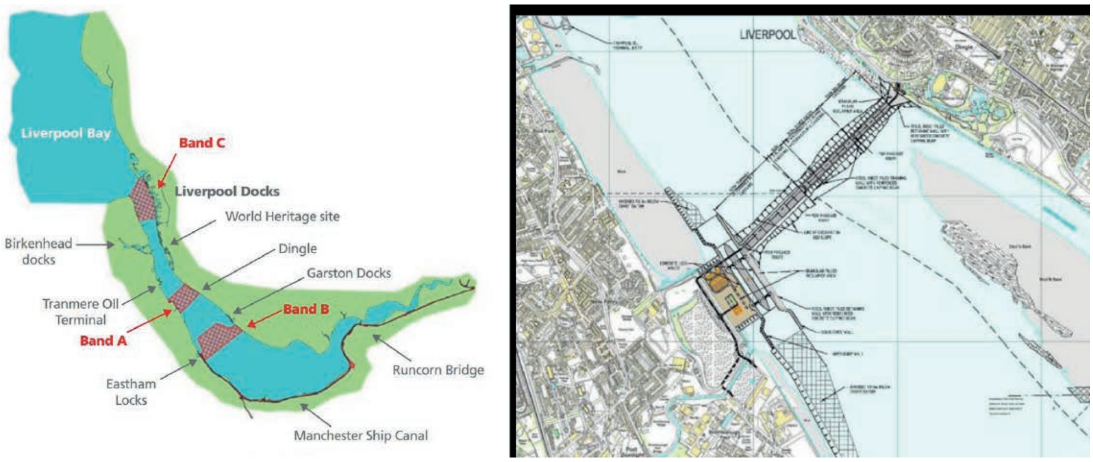

Fig 7 Location of Band A and indicative barrage option between New Ferry and Dingle, from Peel Energy (2011).

(g) Northern Tidal Power Gateways (England)

Promoted by North West Energy Squared Ltd (NWE2) and Northern Tidal Power Gateways Ltd.

This is an initiative promoting a series of six linked (barrage) tidal gateway projects along the north-west coast joined by a new road; across (outer) Solway, Duddon, Morecambe Bay, Ribble, Mersey and the Dee (Figure 8). The Wyre Estuary is excluded, presumably not to conflict with the other tidal power schemes on this estuary or could easily be allowed for by the alignment of the Morecambe Bay barrage option and the direction of the road link. A barrage across the Solway would probably be incompatible with other options in this area.

The tidal gateway schemes appear to be an extension of an earlier NWRDA funded project published in 2009 (Burrows *et al* 2009), and the forerunner to this from the United Kingdom Atomic Energy Authority in 1980 (UKAEA, 1980). This earlier work suggested a potential installed capacity from a combination of estuaries at around 12 GW.

Fig 8 Tidal Gateway Schemes, adapted from Howlett (2016).

Very limited technical information is published at this time, however, the first projects being explored by Northern Tidal Power Gateways Ltd appear to be barrage options across Morecambe Bay and the Duddon Estuary.

Morecambe Bay has a MTR of around 6.3m and Duddon of 5.6m.

www.nwe2.co.uk (site appears to be inactive currently)

(h) Colwyn Bay Tidal Lagoon (Wales)

A potential tidal lagoon with an installed capacity up to 3,200 MW with a 23km seawall impounding an area of around 120sq km (Hendry, 2016). Both Tidal Lagoon Power and North Wales Tidal Energy are identified with this scheme which is likely to have a coastal protection (flood defence) function. Figure 9 shows the likely area of interest within which this scheme is being considered.

Depending on the scale and location of this lagoon there may be associated issues with changes in littoral drift along the North Wales Coast and the sediment supply to the Dee and Mersey estuaries.

MTR is estimated as 5.5m.

www.tidallagoonpower.com/projects/colwyn-bay

www.northwalestidalenergy.com

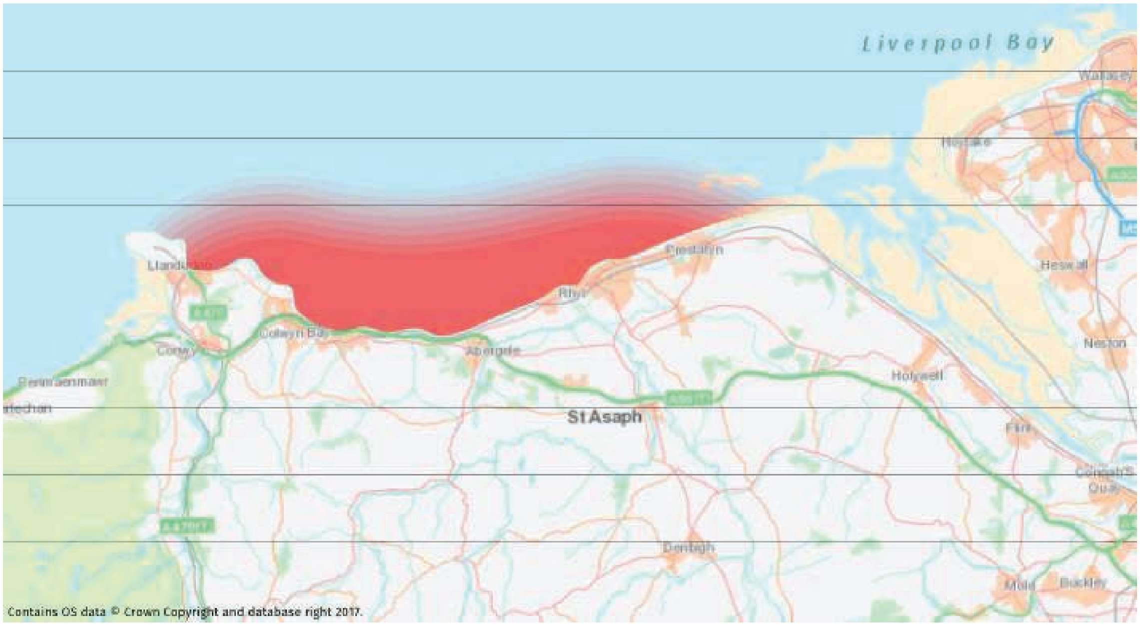

Fig 9 Area of interest for Colwyn Bay Tidal Lagoon (from www.northwalestidalenergy.com).

4.3.2. Bristol Channel

For this research project, the Bristol Channel region extends from the Welsh Border within the Severn Estuary (the UK's estuary with the highest tidal range) down the South West peninsula to Cornwall. Schemes in Welsh Waters which may have a bearing on English Waters are included in the review.

(a) Swansea Bay Tidal Lagoon (Wales)

This scheme is included in the review as the only consented tidal range development in the UK at this time and a scheme widely regarded as a pathfinder project for further lagoon projects. The project provides a valuable basis for the developer and regulatory bodies in establishing the consent requirements for projects of this type. The DCO includes provisions for retention of historic assets (Statutory Instruments, 2015).

The planned installed capacity of this scheme is 320 MW (16 20 MW turbines with 7.2m diameter). A U- shaped impounding structure will enclose an area of 11.5sq km (Figure 10). The final design was arrived at after 14 iterations.

The scheme is the smallest of six lagoons proposed by Tidal Lagoon Power and is relatively distant fromEnglish Waters for Historic England to have concerns.

MTR in Swansea Bay is around 6.58m.

www.tidallagoonpower.com/projects/swansea-bay

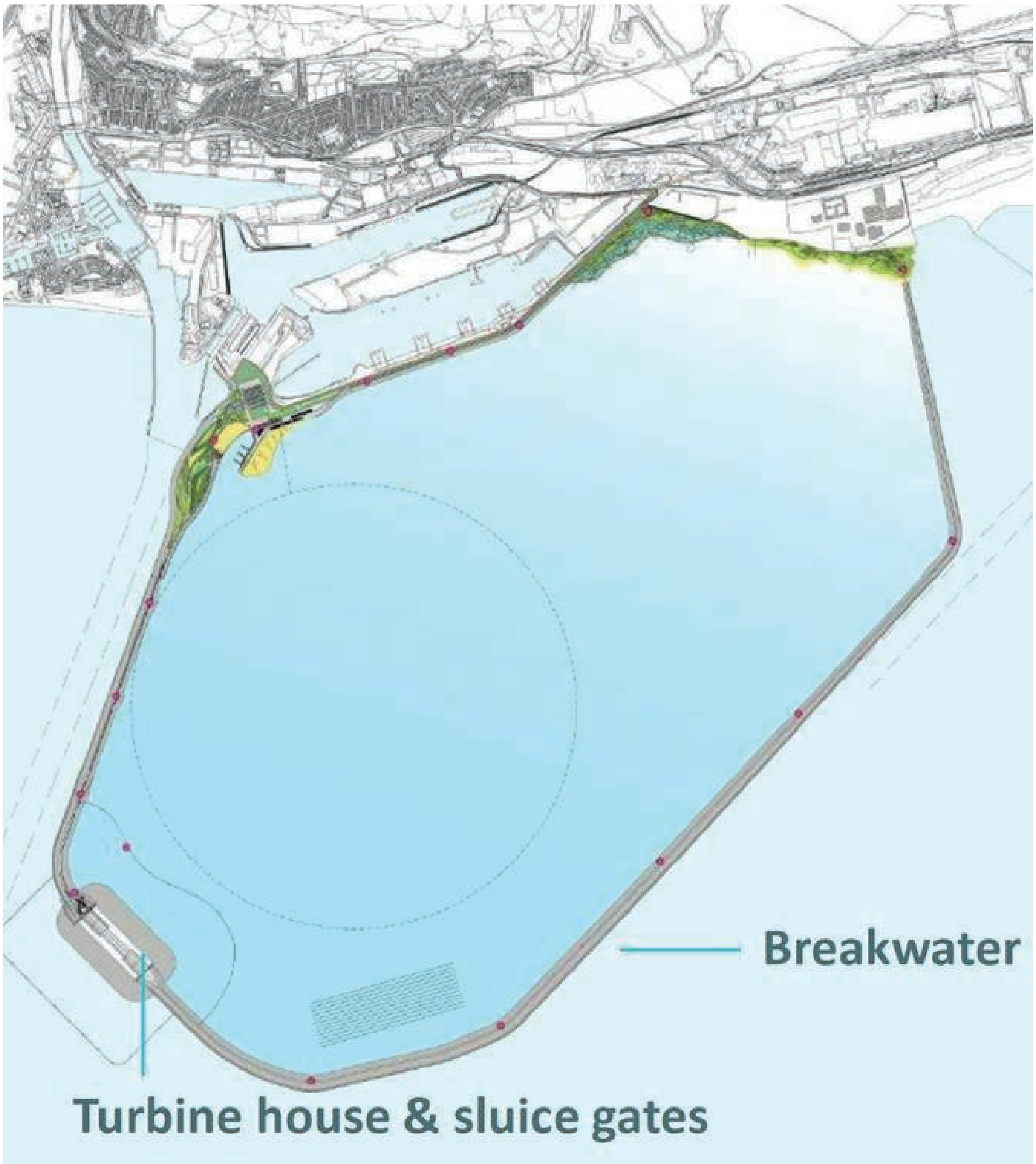

Fig 10 Layout of the Swansea Bay Tidal Lagoon, from Carter (2016).

(b) Stepping Stones Tidal Lagoon (Wales)

A 600 (to 790) MW concept developed by Parsons Brinkerhoff to demonstrate 'A stepping stone to future development of tidal power?' (Parsons Brinckerhoff, 2013). The scheme layout is between Breaksea Point, Llantwit Major and Cold Knap Point, Barry, South Wales (Figure 11), comprising a lagoon wall of 10.6km creating an impoundment of 18sq km. Ebb and flood operating turbines with 8.9m diameter blades would be housed in caisson units in 32m depth. This lagoon option is included for completeness only as the site is identified as part of the set of tidal lagoons on two of four potential development scenarios, 'Value for money' and 'Lowest impact', listed in Table 2 of the Hendry Review (Hendry, 2016).

Unlike Swansea Bay Tidal Lagoon, which is largely isolated from the main axis of the Bristol Channel and located in a large embayment, the Stepping Stones Tidal Lagoon would narrow the channel, leading to effects on flows and sediment transport that translate into the Severn Estuary.

MTR at the site is estimated as 7.7m.

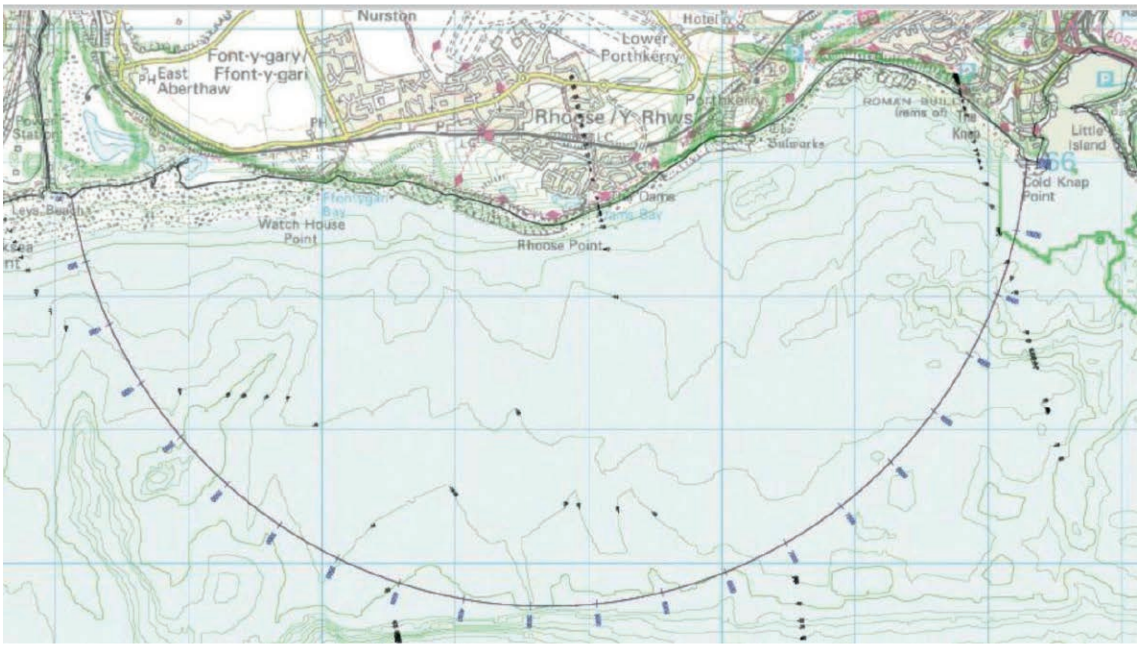

Fig 11 Conceptual layout of Stepping Stones Tidal Lagoon, from Parsons Brinckerhoff (2013).

(c) Cardiff Tidal Lagoon (Wales)

A scheme being actively progressed by Tidal Lagoon Power since 2013 to follow Swansea Bay, with an EIA already in preparation following a completed Scoping Report/Opinion. The project was presented to the Planning Inspectorate in 2014 as a 'Generating Station' type Nationally Significant Infrastructure project with a full DCO application now expected 2019. This is a large lagoon spanning the intertidal and subtidal area of Peterstone Flats between Cardiff and Newport with an impounding wall of around 22km enclosing an area of around 70sq km (Figure 12). The scheme is targeting an installed capacity of around 3,000 MW and is already on a 12th design iteration. Although this site is in Welsh Territorial Waters there will inevitably be many estuary-wide effects which translate into English Waters. Based on present understanding, the following are expected to be a modified through the Severn Estuary; tidal water level profile, tidal flows, sediment pathways and exchanges. There will also be notable changes in the visual landscape, especially apparent around low water (Tidal Lagoon Cardiff Ltd, 2015).

The requirements for compensatory measures are being carefully considered by the developer through their Ecosystems Enhancement Programme (EEP). At present, an approximate 2:1 ratio for loss of intertidal habitat : compensation area is being investigated which may be achieved through a range of sites in both England and Wales, including the east coast of England, to deliver around 2,000 ha of new intertidal habitat (Tidal Lagoon Power, 2016).

MTR estimated at 8.5m for the location of turbines.

www.tidallagoonpower.com/projects/cardiff

Fig 12 Cardiff Tidal Lagoon illustrative layout, showing proximity to English Coast (image provided by Tidal Lagoon Power).

(d) Newport Tidal Lagoon (Wales)

A scheme being considered by Tidal Lagoon Power along with the Cardiff Lagoon. The project was first presented to the Planning Inspectorate in 2015 as a 'Generating Station' type Nationally Significant Infrastructure project.

The project has not yet submitted a Scoping Report and the layout and design iterations for the scheme remain ongoing.

Presently available details suggest this is potentially a large lagoon located upstream of the Cardiff Lagoon with an impounding wall of around 15 to 18km enclosing an area of around 30 to 40sq km. The scheme is targeting an installed capacity of between 1,400 to 1,800 MW. Although this site is in Welsh Territorial Waters there will be many estuary-wide effects which have implications for English Waters, similar to those being assessed for the Cardiff Tidal Lagoon. The in-combination effect of Cardiff and Newport lagoons would be a major consideration for the future character and historic seascape of the estuary.

MTR estimated at 8.7m for the location of turbines in Newport Deep.

www.tidallagoonpower.com/projects/newport

(e) Bridgwater Bay Lagoon (England)

A further scheme presently being considered by Tidal Lagoon Power. There remain various options (bigger and smaller) under consideration at this time with evidence provided to the Hendry Review by Tidal Lagoon Power relating to a 34.1km impounding wall (Brean Down to Minehead) to hold water within an area of 243.2sq km (including the River Parrett and the Hinkley Nuclear Power Station) for power generation from an installed capacity of 6,480 MW. The project remains at the feasibility phase at this time, with the developer giving priority to Swansea and Cardiff lagoons.

For reference, the Bridgwater Tidal Barrier is a separate scheme being constructed on the River Parrett and would only be used to prevent extreme tidal levels from flooding Bridgwater and surrounding areas.

MTR is estimated around 8.3m.

www.tidallagoonpower.com/projects/bridgwater-bay

(f) West Somerset Lagoon (England)

The project was identified to the Planning Inspectorate in 2014 by LongBay SeaPower Ltd as a potential Nationally Significant Infrastructure Project, with an application initially expected in Q2 2018. LongBay SeaPower Ltd is now teamed with Halcyon Tidal Power to promote a project between Culvercliff in Minehead to Lilstock, West Somerset (to west of Hinkley). As of 16 January 2017, the stated scale of the project is a 3,000 (2,995.2) MW installed capacity from 960 3.12 MW turbines, each with a 3.12m runner diameter. The length of the tidal lagoon wall is 28.8km made up of 23.9km of panel caissons, 0.7km embankments from shore and 4.2km from Powerhouses 1 to 6. The resulting enclosed basin would be 140sq km. Figure 13 presents a layout for the lagoon.

The project appears to have completed a feasibility stage with a series of surveys and studies pending before the application is submitted. The project claims to be able to construct in deeper water (using modular panel caisson sea walls with powerhouse caisson interspersed along the enclosure) than a traditional embankment approach would allow. The scheme is based on two-way (ebb-flood) power generation.

MTR at this location is estimated around 7.3m (Watchet).

www.westsomersetlagoon.com

www.halcyontidalpower.com

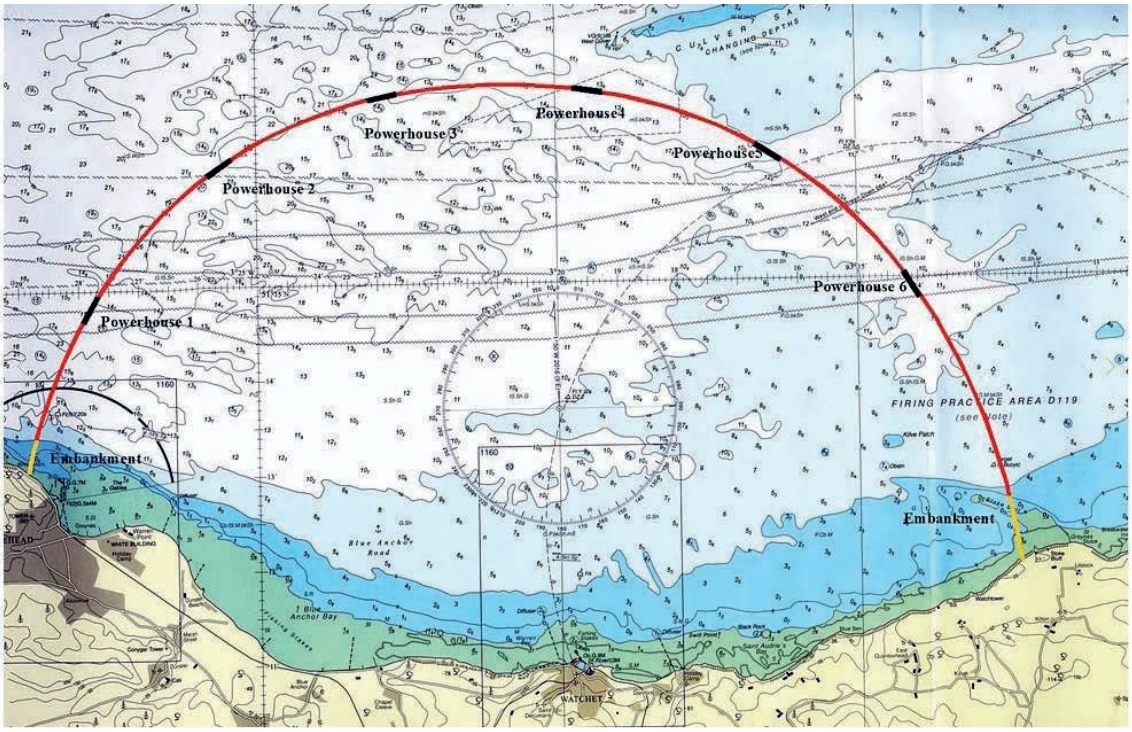

Fig 13 West Somerset Tidal Lagoon indicative layout (www.westsomersetlagoon.com).

(g) Hayle Harbour Power Generation (England)

In 2016, a study examined the technical and economic feasibility of installing small-scale tidal range power technologies, in the order of 120 kW of installed capacity, to make use of historic tidal pools (Carnsew and Copperhouse Pool (Figure 14), created by former local copper industries to help sluice out the shipping channel of accumulated fine sands) (Mojo Maritime, 2016). The Port of Hayle is part of the Cornwall and West Devon Mining Landscape WHS (www.historicengland.org.uk/listing/the-list/list-entry/1000105) and elements of the harbour complex are protected as Listed Buildings and Scheduled Monuments.

MTR is around 4.2m (St Ives).

The study was commissioned by Community Energy Plus.

www.cep.org.uk

A spin-off company now exists called Tide Mills Ltd who aim to promote small and community scale tidal range and tidal stream energy projects around the world.

www.tidemills.co.uk

Fig 14 Copperhouse and Carnsew Tidal Pools, Hayle.

4.3.3. Eastern English Channel

For this research project, the Eastern English Channel region extends from Brighton to Dover, and also includes some areas within the Thames Estuary.

The tidal range in this region only marginally exceeds the criteria for a potential resource. If MTR for economic viability was raised to greater than 5m then most of this region would most likely be reduced to locations within the Thames Estuary only, and where the tidal range is amplified from the open coast up to 5.5 m (see Section 3.2.2). The Hendry Review refers to this region as 'South East' and speculates schemes at Sheerness, Thames Estuary and Sussex Coast, also recognising that if the threshold for economic viability was greater than 5m these sites would probably not be included (Hendry, 2016). Nevertheless, a hypothetical scheme at Sheerness remains in two of the four illustrative portfolios of tidal lagoons.

There are currently no known active proposals in this area.

(a) Thames Reach Airport (England)

In 2013, a scheme was developed for submission to the Airports Commission which included a 20 MW tidal lagoon on the Hoo Peninsula, Thames Estuary (Thames Reach Airport Ltd, 2013). The project consortium included Metrotidal Ltd who was responsible for the tunnel and tidal power elements of the submission (Metrotidal Ltd, 2013). A tidal lagoon structure was proposed comprising two tidal pools which also act as flood storage or offered an additional area for pumped storage. The western pool (High/Pool 1) impounded an area of 10.7sq km for normal tidal power operation but this could be increased to 16sq km as flood/pumped storage. The eastern pool (Low/Pool 2) impounded an area of 16.2sq km.

The full scheme was not short-listed by the Airports Commission and is therefore considered dormant at this time, however, the original Metrotidal components (flood defence, transport and tidal power) of the project (Figure 15) existed prior to integration with the airport proposal and the possibility is these elements could be evaluated again in the near future.

MTR at this location (Canvey) in the Thames Estuary is around 4.6m.

www.thamesreachairport.com

www.metrotidal.com

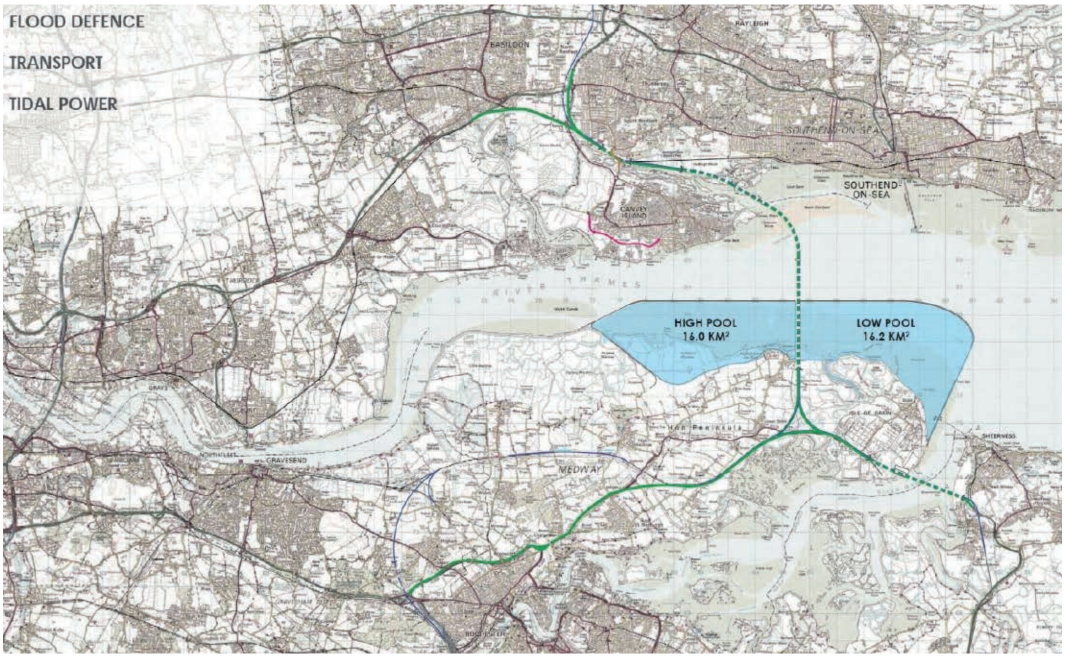

Fig 15 Tidal lagoon proposal on Hoo Peninsula, from Metrotidal Ltd (2013).

4.3.4. The Wash to the Humber Estuary

For this research project, The Wash to the Humber Estuary region extends between these two estuaries along the East Lincolnshire coast. The Hendry Review refers to this region as 'East Coast'.

Like the Eastern English Channel Region, if the threshold for economic viability was greater than 5m then this region would probably largely reduce to a few areas within the Humber Estuary only.

There are presently no known active proposals in this area.

(a) The Wash Tidal Barrier (England)

The Wash Tidal Barrier Corporation was incorporated in 2008 to promote an 18km long barrage/flood barrier across The Wash. The scheme immediately drew strong opposition from the RSPB. The development company is presently listed as dormant.

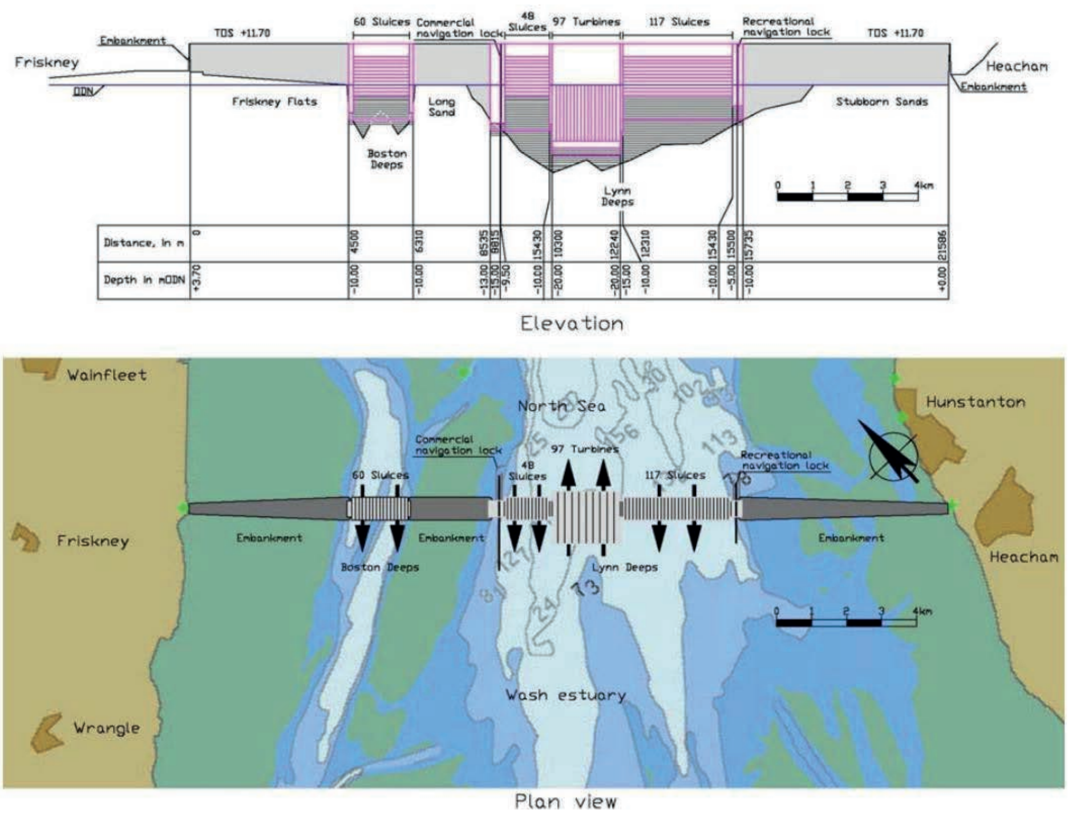

Fig 16 Conceptual design of The Wash storm surge barrier and tidal power plant, after Hofschreuder (2012).

A scheme conceptual design was developed in 2012 as part of a MSc project (Hofschreuder, 2012) which posed the research question: 'To what extent is it possible and attractive to combine the closure of the Wash estuary with the generation of renewable energy from the tides?' An ebb generation scheme, equipped with 97 bulb turbines and 225 sluices turned out to be the most optimal design (Figure 16). The tidal power plant comprised of an installed power of 940 MW, with a turbine diameter of 8m.

MTR is estimated to be 4.7m.

www.washbarrier.org

4.4 Summary of known interests

Table 2 provides a summary of known (active and recent) interest in tidal range developments adjacent to, and within, English Waters. The information is presented without prejudice to any project, the potential for competition between projects for sites, concerns about energy reduction across any region from multiple schemes affecting individual project viability, any significant environmental impact (or cumulative impact) or the requirements for compensatory measures. The information is offered to help identify the present level of interest in tidal range developments and any discernible regional bias of such interest.

Table 2 Summary of known interest in tidal range developments adjacent to, and within, English Waters.

Region	Number of Projects and Type	Estimated Installed Capacity (MW)
Eastern Irish Sea	8 barrages	17,860
Bristol Channel	7 lagoons	15,200
Eastern English Channel	1 lagoon	20
The Wash and Humber	1 barrage	940

Across the regions 22 separate projects have been identified with an estimated total installed capacity of around 34 GW. This includes the Swansea Bay Tidal Lagoon.

The Eastern Irish Sea is shown to have the greatest level of present interest, but the larger set of projects is targeting the Bristol Channel (based on average installed capacity).

Most projects in the Eastern Irish Sea appear to be barrage options with proposals for every major estuary in the region; Solway, Duddon, Morecambe Bay, Wyre, Ribble, Mersey and Dee.

Most projects in the Bristol Channel Region appear to be lagoon options, setting aside the Severn Tidal Barrage as scheme which is no longer being pursued or has present Government support.

There appears to be much less interest in developing projects in the Eastern English Channel or in The Wash and Humber regions, largely explained by the reduced amount of technical resource (smaller areas and lower tidal range).

4.5 Status of developer activity

The present review shows that different developers are at different stages in their projects.

To date, the most advanced project is the Swansea Bay Tidal Lagoon which received a DCO in 2015. The development costs to this point are estimated as £35 million. The capital investment to build this project is estimated to be £1.3 billion (www.tidallagoonpower.com/projects/swansea-bay). The project is presently awaiting agreement from Government for a guaranteed price for electricity before the reaching financial close to build the project.

Other projects have moved from site selection and are examining project feasibility to develop a conceptual design which can then be taken through an environmental impact assessment to support stakeholder engagement and project consenting.

Three projects have identified their intent to submit an application to the Planning Inspectorate, however these projects still all remain at the pre-application stage (Cardiff, Newport and West Somerset Tidal Lagoon – all from the Bristol Channel Region). No 'large' projects have yet registered their intent with the Planning Inspectorate in the Eastern Irish Sea Region, noting that only larger schemes in excess of 100 MW of installed capacity qualify as nationally significant renewable energy infrastructure.

As each stage in the project development process is relatively more costly, the general position is that most developers have put their activities on hold until there is clarity from Government in their decision on the Swansea Bay Tidal Lagoon, as well as the long awaited response to the Hendry Review in regards to the appetite for a national programme of tidal range development.

5. REVIEW OF APPLICABLE POLICY AND LEGISLATION

5.1 Overview

This section provides a review of presently available and applicable policy and legislation that might (generally) apply to the types of developments identified in this review.

The potential remains for variations to existing policy and legislation in the near future when the Government responds to the Henry Review, considers a revised National Policy Statement to provide specific recognition to tidal range schemes and deals with the implications of leaving the European Union to issues such as environmental legislation.

Whilst many different forms of policy and legislation need to be taken into consideration to support the development and consenting of a tidal range project, only those that are of relevance to the historic environment have been commented on here.

Finally, the focus is on national policy and relevant legislation rather than variants in devolved administrations of Scotland, Wales or Northern Ireland.

5.2 General approach to consenting (Large Projects)

As noted above, the term 'large project' is likely to relate to existing thresholds of installed capacity in the existing National Policy Statement (NPS) for Renewable Energy Infrastructure (DECC, 2011), which is likely to apply to projects with an installed capacity above 100 MW. However, the present revision of the policy does not make specific reference to tidal range developments. Hendry indicates that tidal range developments above 500 MW will warrant a distinct NPS.

Large projects will be regarded as a NSIP and require an application to the Planning Inspectorate (using the Planning Act 2008) for consent (Development Consent Order – DCO), which is considered by the Secretary of State. The Marine Management Organisation (MMO) defers responsibility to the Planning Inspectorate for any NSIP, however, a marine licence would still be required from the MMO for any development at sea in English Waters.

The application process has six stages that seek to adhere to a defined timetable (www.infrastructure.planninginspectorate.gov.uk/application-process/the-process/). All six of these stages fall within the Pre-Construction phase:

- **Pre-application** – this is the period when stakeholder consultation on the proposed project is expected to commence and to enable constructive feedback to help influence the project. Project Scoping for EIA requirements is likely to take place at this stage which would need to align with relevant legislative requirements, presently Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (as amended) for any scheme determined to be a NSIP.

- **Acceptance** – this would be the period when an Environmental Statement is submitted as part of the application process to consider the full implications of the project, including any compensatory measures. Once the application is submitted, the Secretary of State has up to 28 days to accept or reject the application.

- **Pre-examination** – 3-month period where parties can register their interest and provide a summary of their views for or against the application.

- **Examination** – 6-month period to complete the examination with evidence presented at hearings and a response made in writing.

- **Decision** – the Planning Inspectorate will offer the Secretary of State their recommendation within a 3-month period from the completion of the examination period. The Secretary of State is then expected to make a final decision within a further 3-month period.

- **Post-decision** – a 6-week period to allow for any challenge (Judicial Review) in the High Court.

5.3 Small and Intermediate Projects

The terms 'small' and 'intermediate' project (see Section 2.2) is likely to apply to a scheme targeting an installed capacity under 100 MW (or under 30 MW in the context of 'small'). However, a small or intermediate (power generating) project in this context does not necessarily infer a small footprint or a small amount of impact and normal EIA requirements are expected to apply to all tidal range schemes, irrespective of their installed capacity.

For small and intermediate marine power generation projects, Section 36 – Consent of the Electricity Act 1989 (Energy Bill) is likely to provide the relevant legislation for construction of generating stations. The MMO will most likely be the lead competent authority for projects in English Water. Section 36 is applicable up to the seaward limits of the territorial sea or a Renewable Energy Zone, when designated.

Onshore elements of such projects may be subject to the Town and Country Planning Acts, administered by the relevant Local Planning Authority. There is a Coastal Concordat (Defra, 2013) to co-ordinate consenting processes between the MMO, LPAs and other regulatory bodies in the coastal zone.

5.4 Existing Policy

5.4.1. National Policy Statement for Energy (NPS-EN)

Existing Government energy policy includes the NPS for renewable energy infrastructure (EN-3), noting that tidal range schemes are not presently covered. This document is likely to be revised or a separate policy developed (DECC, 2011), however, the need for such a revision may also now depend on how the Government responds to the Hendry Review, which calls for a specific NPS for large tidal lagoons. If the recommendation for a strategic programme of development is supported, then a Strategic Environmental Assessment (SEA) of such a programme may be required (see Section 5.5.1).

NPS EN-3 has to be read in conjunction with the Overarching National Policy Statement for Energy (EN-1) (DECC, 2011), which includes policies on generic impacts on the historic environment relating to the applicant's assessment, decision-making, and mitigation (recording).

Historic England should ensure their advice informs any new NPS being developed for tidal range developments.

5.4.2. UK Marine Policy Statement (UK MPS)

The UK MPS (HM Government, 2011) is the statutory policy for the UK Marine Area and is given effect through the Marine and Coastal Access Act (MCAA) 2009. Section 44 of the Act sets out the basis for the UK MPS as a tool to support marine planning, including the preparation of marine plans and implementation of marine licensing. The UK MPS states that when decision makers are examining and determining applications for energy infrastructure and marine plan authorities are developing Marine Plans they should take into account:

> *The potential impact of inward investment in offshore wind, wave, tidal stream and tidal range energy related manufacturing and deployment activity; as well as the impact of associated employmentopportunities on the regeneration of local and national economies. All of these activities support the objective of developing the UK's low carbon manufacturing capability.*

The UK MPS also sets out the Government's policies with respect to the historic environment and to seascape in the UK Marine Area. With respect to heritage assets, the UK MPS includes the following statement:

> *2.6.6.3 The view shared by the UK Administrations is that heritage assets should be enjoyed for the quality of life they bring to this and future generations, and that they should be conserved through marine planning in a manner appropriate and proportionate to their significance. Opportunities should be taken to contribute to our knowledge and understanding of our past by capturing evidence from the historic environment and*

making this publicly available, particularly if a heritage asset is to be lost.

The policies set out in the UK MPS apply to non-designated as well as designated heritage assets:

> *2.6.6.5 Many heritage assets with archaeological interest ... are not currently designated as scheduled monuments or protected wreck sites but are demonstrably of equivalent significance. The absence of designation for such assets does not necessarily indicate lower significance and the marine plan authority should consider them subject to the same policy principles as designated heritage assets (including those outlined) based on information and advice from the relevant regulator and advisors.*

Policies with respect to heritage assets that may be affected by development proposals are elaborated as follows:

> *2.6.6.7 In considering the significance of heritage assets and their setting, the marine plan authority should take into account the particular nature of the interest in the assets and the value they hold for this and future generations. This understanding should be applied to avoid or minimise conflict between conservation of that significance and any proposals for development.*
>
> *2.6.6.8 The marine plan authority, working with the relevant regulator and advisors, should take account of the desirability of sustaining and enhancing the significance of heritage assets and should adopt a general presumption in favour of the conservation of designated heritage assets within an appropriate setting. The more significant the asset, the greater should be the presumption in favour of its conservation. Substantial loss or harm to designated assets should be exceptional, and should not be permitted unless it can be demonstrated that the harm or loss is necessary in order to deliver social, economic or environmental benefits that outweigh the harm or loss.*
>
> *2.6.6.9 Where the loss of the whole or a material part of a heritage asset's significance is justified, the marine plan authority should identify and require suitable mitigating actions to record and advance understanding of the significance of the heritage asset before it is lost. Requirements should be based on advice from the relevant regulator and advisors.*

The UK MPS adopts the definition of landscape in Article 1 the European Landscape Convention 2000 as 'an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors'. The UK MPS goes on to state that references to seascape should be taken as meaning landscapes with views of the coast or seas, and coasts and the adjacent marine environment with cultural, historical and archaeological links with each other. The UK MPS includes the following policy on seascapes affected by development:

> *2.6.5.3 In considering the impact of an activity or development on seascape, the marine plan authority should take into account existing character and quality, how highly it is valued and its capacity to accommodate change specific to any development ...*

The UK MPS also includes a policy on nationally designated areas such as Areas of Outstanding Natural Beauty (AONBs), National Parks or Heritage Coasts. Such designated areas are likely to encompass heritage assets and important landscapes/seascapes but they are typically addressed in their own right and, as such, are beyond the scope of this document.

5.4.3. National Planning Policy Framework

Where elements of a tidal range scheme are within – or have effects within – the boundary of the Local Planning Authority (that is on land, in the intertidal area and sometimes in sub-tidal areas also) the consenting process is likely to take account of the National Planning Policy Framework (NPPF) (DCLG, 2012).

Conserving heritage assets in a manner appropriate to their significance, so that they can be enjoyed for their contribution to the quality of life of this and future generations, is one of the 12 Core Planning Principles stated in paragraph 17 of the NPPF.

Specific policies on designated and non-designated heritage assets and the historic environment, including landscapes, are set out throughout the NPPF and supported by Planning Practice Guidance (www.gov.uk/guidance/conserving-and-enhancing-the-historic-environment).

Consenting is also likely to be informed by Historic England's Good Practice Advice (GPAs) on managing significance (Historic England, 2015) and setting and views (Historic England, 2015).

5.4.4. Marine Plans

The UK MPS supports the development of Marine Plans, which are regional plans which are split between inshore (out to 12 nautical miles) and offshore areas (out to limit of the Exclusive Economic Zone (EEZ)). Tidal range developments would tend to be limited to shallow water areas and are therefore not expected to be under consideration for any of the offshore plan areas.

The tidal range development sites of present interest identified above fall within the following marine plan areas (Figure 17):

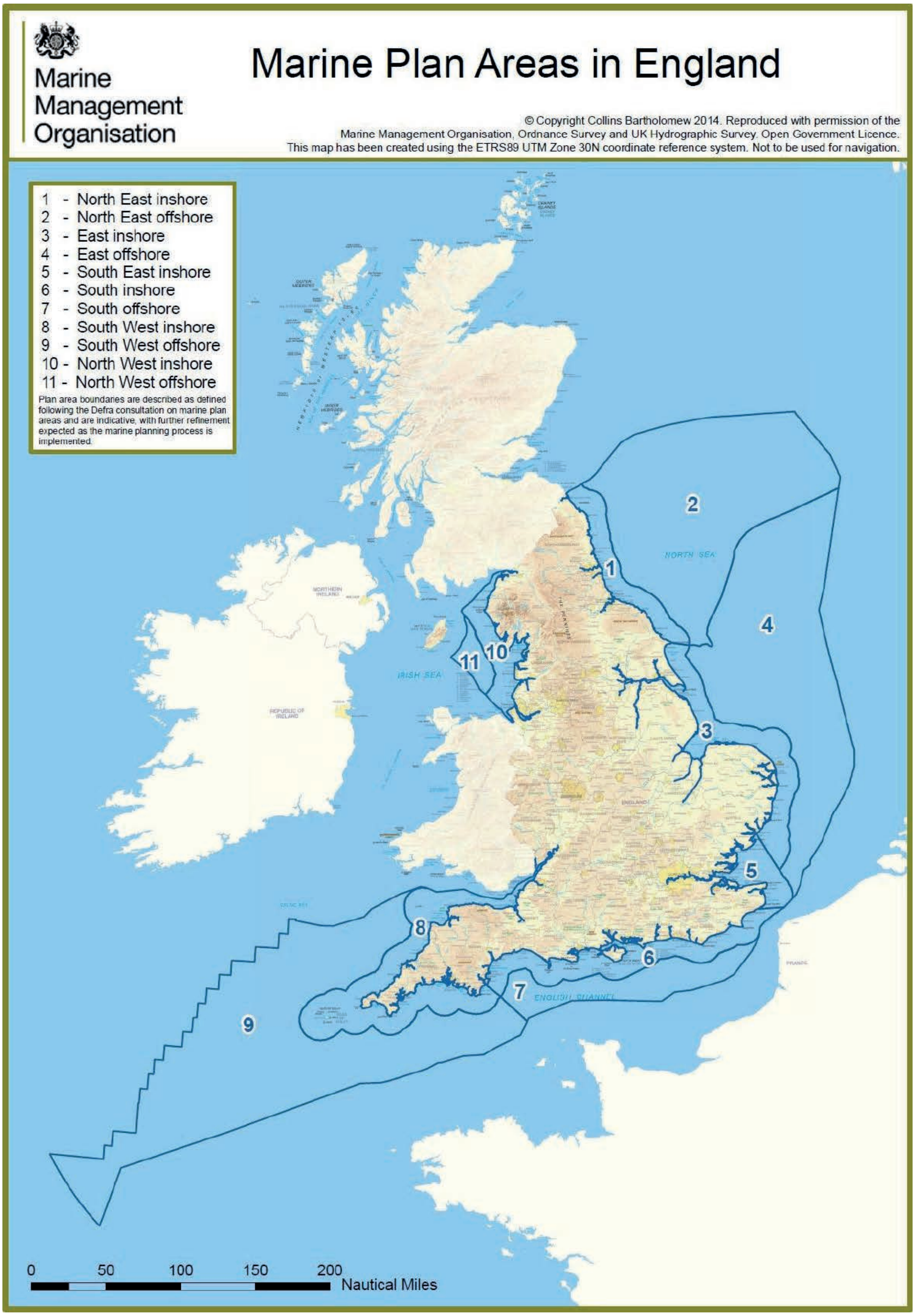

Fig 17 Marine Plans Areas in England (www.gov.uk/government/uploads/system/uploads/attachment_data/file/325688/marine_pl an_areas.pdf)

- North West
- South West Inshore
- East Inshore
- South East Inshore

The East Inshore and Offshore marine plans were published in April 2014 but did not expressly include tidal range developments due to the complexity of potential impacts (HM Government, 2014). However, the East Marine Plans did include a specific objective on heritage assets and landscapes, together with a specific plan policy:

Policy SOC2 Proposals that may affect heritage assets should demonstrate, in order of preference:

a) that they will not compromise or harm elements which contribute to the significance of the heritage asset

b) how, if there is compromise or harm to a heritage asset, this will be minimised

c) how, where compromise or harm to a heritage asset cannot be minimised it will be mitigated against or

d) the public benefits for proceeding with the proposal if it is not possible to minimise or mitigate compromise or harm to the heritage asset

At the time of producing this review, the remaining Marine Plans relevant to areas of interest for tidal range developments are currently in development for the North West and South West marine plan areas. Both these plans are giving direct consideration to potential tidal range developments alongside other forms of renewable energy) tidal stream, wave and wind). No similar considerations are yet made in the South East plan for renewable energy.

Although covering areas beyond English Waters, the draft Welsh National Marine Plan (Welsh Government, 2017) has recently been published for consultation (consultation closed on 29 March 2018). Supporting policy ELC_01: Low carbon energy (supporting) refers to tidal lagoon schemes within specific resource areas (RA), noting this policy does not make any specific reference to tidal barrages. The resource areas are identified in Figure 18 and are consistent with the project locations previously identified in Welsh Waters in Section 4.

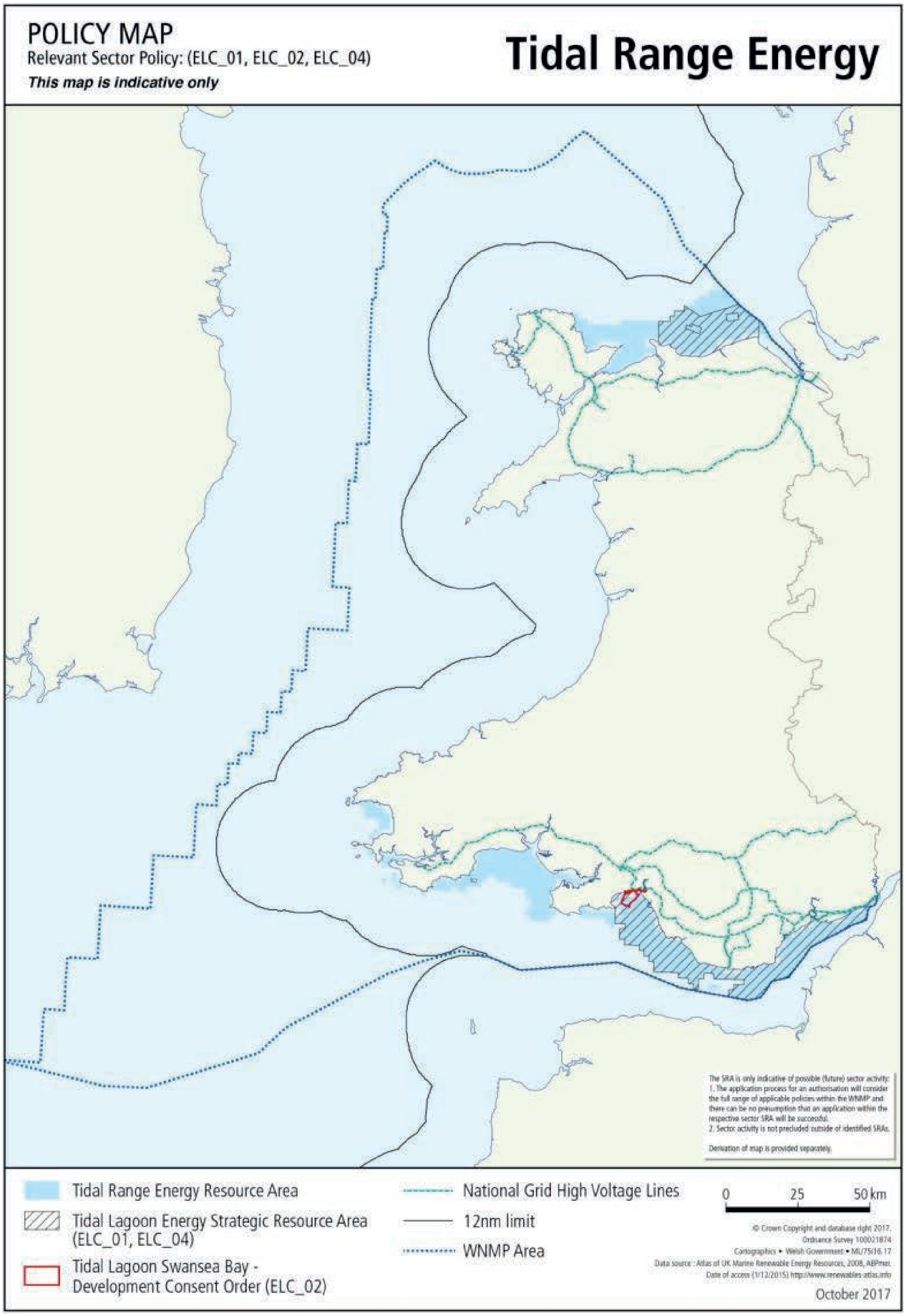

Fig 18 Welsh Tidal Range Energy Resource Areas, reproduced from Welsh Government (2017).

5.4.5. Heritage designations

Marine and land planning policies provide protection to designated as well as non-designated heritage assets, but some of these designations also confer direct legal protection. In the marine zone, including both sub-tidal and intertidal areas, legal protection may be conferred by the Protection of Wrecks Act 1973 or the Ancient Monuments and Archaeological Acts 1979. Works within the area of a protected wreck or a scheduled monument require specific consent under these Acts that is additional to development consent. Tidal range developments may also affect Listed Buildings and be subject to Listed Building Consent from the Local Planning Authority by virtue of the Planning (Listed Buildings and Conservation Areas) Act 1990. The setting of these, and other designated heritage assets, are protected by planning policy.

5.5 Hendry Review

The Hendry Review was set up to assess - for the Secretary of State for Business, Energy and Industrial Strategy (BEIS) - the strategic case for tidal lagoons and whether they could represent value for money to the consumer. Although the focus of the review initiated with tidal lagoons, other tidal range developments were also considered, with the general view that small scale barrages were confirmed within the in terms of reference.

The review reported to Government at the end of 2016, stating that tidal lagoons have an important role to play in national energy security, decarbonisation and the ability to deliver wider economic benefits to the regions and that there should be a Government strategy in place to help this happen (Hendry, 2016). Government is expected to respond to the detailed recommendations made in the Hendry Review in due course, with a related but separate decision yet to be made on the electricity strike price for Swansea Bay Tidal Lagoon.

Uncertainty remains at this time on what form of response Government will make, with various outcomes possible.

If Government chooses to back the recommendations made by the Hendry Review, then investor confidence in projects will likely increase and the majority of schemes which may presently lay dormant can be expected to move forwards again at pace.

If Government decides that other renewable energy options present better value to the public, then individual tidal range schemes may still be able to progress but each one would need to consider how to achieve a competitive cost of energy in a rapidly changing market.

Amongst a wide range of conclusions and recommendations, the following aspects of the Hendy Review are of particular relevance from a historic environment perspective:

- The recommendation that there should be a Government-led programme of (large) tidal range developments rather than a piecemeal approach.
- The conclusion that tidal range developments will bring wider benefits including flood prevention, regeneration and recreation.
- The recommendation that work should be done to assess possible tourism impacts.
- The recommendation that there should be a specific National Policy Statement for tidal range development.
- The recommendation that sites suitable for development should be designated by the Government as part of the NPS.
- The recommendation that smaller scale projects continue to be developed and constructed while the programme of larger scale projects is still under way.
- The recommendation to establish a Tidal Power Authority at arms-length from Government.
- The recommendation that the Tidal Power Authority should undertake some of the environmental assessment work for the location of tidal range developments or incentivise the Crown Estate to do this.
- The recommendation that investors bid by competitive tender to develop the sites identified in the NPS.
- The emphasis placed on local community interests – and the role of local authorities – in the consenting process.
- The recommendation that the seawalls of tidal range developments should be regarded as permanent for the purposes of decommissioning.

If Government chooses to back these recommendations, then Historic England will need to align its advice to a programme of large developments, including the selection of sites and the conduct of some environmental assessment, being developed within Government (or the Tidal Power Authority) rather than by individual investors. However, Historic England would still need to be capable of advising on any separate ‘small’ (that is non-NSIP) developments – which may be large projects in themselves – that may continue to emerge from individual developers through existing consenting processes.

5.5.1. Strategic Environmental Assessment (SEA)

If Government proceeds with a programme of tidal range development, then the requirement still exists, under present legislation, to complete a

Strategic Environmental Assessment (SEA) of likely significant effects on the environment brought about by the implementation of such a programme. This SEA would need to include the historic environment, referred to as 'cultural heritage, including architectural and archaeological heritage'.

The SEA is an existing EU Directive (Directive 2001/42/EC on the assessment of the effects of certain plans and programmes on the environment), so the further link here might be the way the SEA is dealt with in the Great Repeal Bill concerning the UK's departure from the European Union.

There is already SEA in place which includes for tidal range developments, the Offshore Energy Strategic Environmental Assessment (OESEA3).

OESEA3

BEIS (formerly DECC) is the Government department currently responsible for the Offshore Energy Strategic Environmental Assessment (OESEA). Historic England is a consultee in the process.

OESEA3 is the current plan and programme and was adopted in July 2016 following a consultation period. The Environmental Report for OESEA3 has an indicative time horizon (that is period of currency) of 5 years. During this period, there will be a programme of technical studies to help inform the SEA process.

What is notable is that the scope of OESEA3 already includes tidal range as part of the mix of marine renewable energy options for licensing/leasing:

> *Consider the environmental implications of DECC's draft plan/programme to enable further licensing/leasing for offshore energy (oil and gas, hydrocarbon gas storage, carbon dioxide storage and marine renewables including wind, wave, tidal stream and tidal range). This includes consideration of the implications of alternatives to the draft plan/programme and consideration of potential interactions with other users of the sea.*

Landscape and seascape are included as part of the scope of OESEA3 and notes that:

> *Tidal range developments have the potential to generate direct changes to the character of coastal landscapes and seascapes through the imposition of lagoon walls/barrages and turbine housings, related lighting etc. resulting in, for example, foreshortening of seascape views and the introduction of industrial components.*

Historic England was consulted on the draft OESEA3 report and has sought to modify one of the sources of potential effect on the marine environment, specifically:

Physical damage to submerged heritage/archaeological contexts from infrastructure construction, vessel/rig anchoring etc. and how the setting of any coastal historic environmental assets might be affected and loss of access. (DECC, 2016)

5.5.2. Tidal Power Authority

A further implication of the future direction and pace of any programme of tidal range development (tidal lagoons and small-scale barrages) is whether the Government adopts the recommendation of a Tidal Power Authority, having clarified the full remit of this body in any new NPS.

The remit of a Tidal Power Authority may include early project development work, identifying appropriate sites, environmental assessments and negotiations with The Crown Estate and land owners. These roles could readily wash away existing private sector development activity identified in this review.

The role of a Tidal Power Authority could eliminate potential conflicts between sites for the technical resource and offer a co-ordinated approach to achieving successful compensatory measures at a programme scale rather than separately for individual projects. The role could also ensure a consistent standard to EIA, including the consideration of risk to heritage assets.

If the Government accepts the recommendation that a Tidal Power Authority be established, then the new authority would be a key focus for Historic England advice.

5.6 Potential implications of Britain exiting the European Union (BrExit)

Most environmental legislation in the UK is adopted from European Union (EU) directives. Britain exiting the EU requires full conversion of this legislation into UK law, a process being led by the Department for Exiting the European Union and being implemented through the European Union (Withdrawal) Bill 2017-19 (UK Parliment, 2018).

The most recent departmental publication on the subject of environmental protections (Department for Exiting the European Union, 2018) summarises the key issue relating to plans to ensure environmental responsibilities are not weakened.

'The Withdrawal Bill will convert the existing body of EU environmental law into domestic law, making sure the same protections are in place in the UK and laws still function effectively after the UK leaves the EU.'
'This Government is committed to being the first generation to leave the natural environment in a better state than we inherited it. Leaving the EU means we now have a unique

opportunity to design a set of policies to drive environmental improvement with a powerful and permanent impact, tailored to the needs of our country.'

On this basis, 'BrExit' would appear to present little risk to environmental legislation and standards as the UK Government intends to keep in place immediately after withdrawal those EU environmental laws and rules that currently apply in the UK, 'wherever practicable and sensible'.

There remain some subtleties to monitor:

- After exiting the EU, the UK Government will have the powers to legislate changes to environmental legislation to meet their overall commitment to 'improve the environment within a generation'. Any such future change to the regulatory framework would remain subject to consultation.

- The Government's vision on the future provisions to improve the environment have also just been published (HM Government, 2018). This plan recognise the need to protect key natural and heritage assets though the planning system.

- Should a conflict arise between preserved EU-derived law and new primary legislation then newer legislation will take precedence.

- Legislation that is within the competence of the devolved legislatures or ministers giving effect to EU law will also need to be amended. The issue here would be to ensure devolved administrations work together for consistency and implementations that occur at the same phase, especially for their approaches to NSIPs.

- Investor confidence in major projects will want further certainty in the outcomes from BrExit.

6. TYPES OF HERITAGE ASSETS AND POTENTIAL IMPACTS

6.1 Overview

This section reviews the types of heritage assets that might be associated with areas identified for tidal range development. The review is intended as a refinement to the general advice provided by *Historic Environment Guidance for Wave and Tidal Energy* (HEGWTE) (English Heritage, 2013), but now focuses specifically on tidal range developments. This section adopts comparable terminology and can be read in conjunction with the existing guidance.

The UK MPS uses the term 'historic environment' to refer to all aspects of the environment resulting from the interaction between people and places through time, including all surviving physical remains of past human activity, whether visible, buried or submerged (HM Government, 2011). Specific elements of the historic environment – buildings, monuments, sites or landscapes – that have been positively identified as holding a degree of significance are referred to as 'heritage assets'.

HEGWTE identifies five heritage asset themes likely to be associated with any type of marine renewable energy development:

(a) submerged prehistory

(b) maritime activity

(c) coastal activity

(d) aviation; and

(e) terrestrial activity

HEGWTE also distinguishes five environments in which heritage assets may be encountered, listed here from seaward to landward:

(a) far from shore

(b) close to shore

(c) crossing shoreline

(d) on land; and

(e) further afield

Existing guidance also recognises that heritage assets can be found below ground level, at ground level, and upstanding above ground level (ground level and seabed level are regarded as synonymous). The generic relationship between the different heritage asset themes and their likely location in the marine environment is summarised in Figure 19, noting exceptions to this relationship are not ruled out. The 'marine environment' is regarded as encompassing all environments within the UK Marine Area, that is both sub-tidal and intertidal environments including tidal rivers and estuaries up to the limit of Mean High Water Spring (MHWS) tides. Areas landward of the MHWS boundary are referred to as 'land', encompassing heritage assets on the shoreline that might be susceptible to coastal erosion or flooding. As well as specific heritage assets and their settings, consideration also has to be given to the broader landscape or seascape, whose significance may be based in part on historical or archaeological elements and associations, sometimes referred to as 'historic character'. Landscapes and seascapes may encompass both land and sea and be appreciated seaward from the land and landward from the sea.

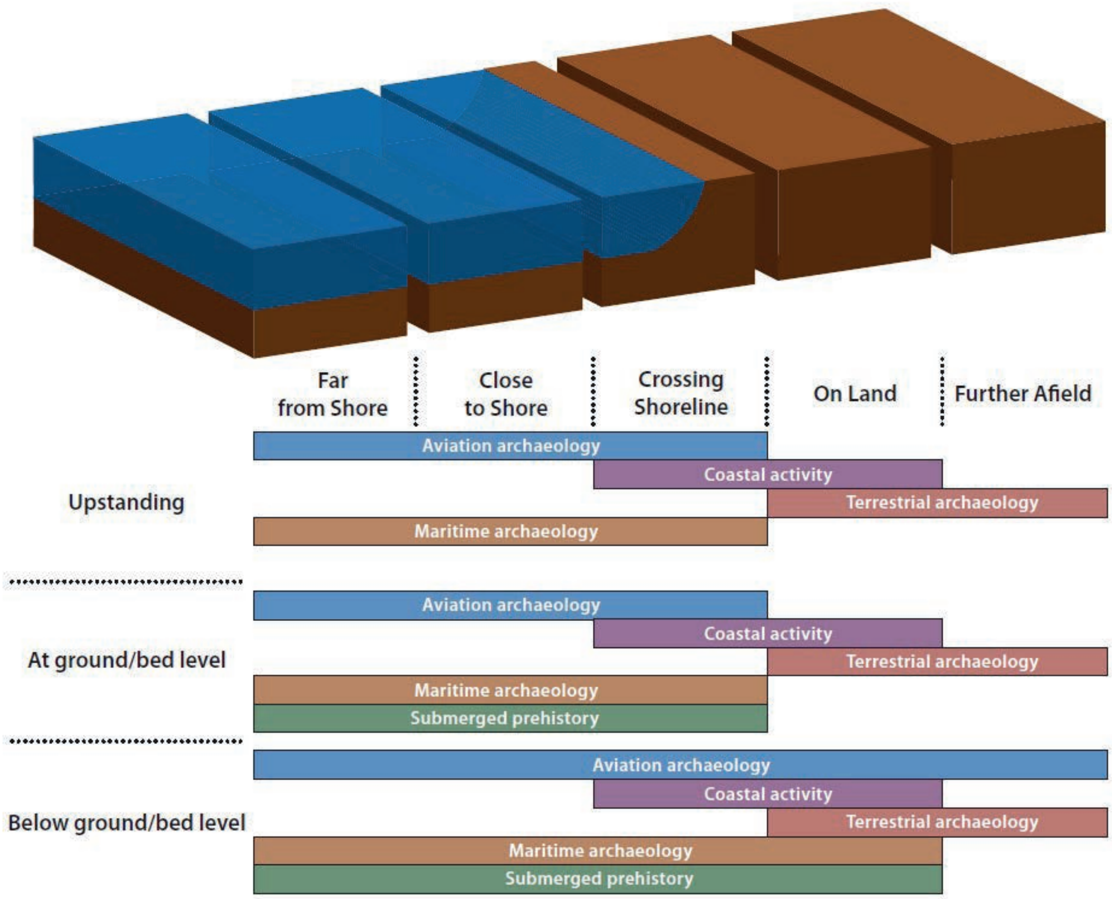

Fig 19 Range of historic environment topics that may be raised by a tidal range development (English Heritage, 2013).

In terms of their immediate footprint, most tidal range developments are expected to occupy locations 'Crossing Shoreline'. The exception to this generalisation is 'offshore lagoons' which may be located 'Close to Shore' or 'Far from Shore', depending on site conditions such as suitable water depths. Inevitably, some infrastructure of any type of development is likely to reside 'On Land' beyond the 'Crossing Shoreline' environment, such as powerlines and sub-stations between the cable landfall and grid connection.

Considerations 'Further Afield' on land (and from sea) are likely to be restricted to questions about long- range visual impacts of structures on the historic environment, noting that there will be a distinctive difference between the appearance of schemes seen at high and low waters. Other visual impacts might also be a consideration 'Far from Shore', related to the consequence of an operating scheme influencing water levels and currents, especially if multiple schemes might lead to a larger in-combination effect.

Given the likely focus on 'Close to Shore' and 'Crossing Shoreline' environments for tidal range developments, the generic relationship presented in Figure 19 suggests that heritage assets relating to submerged prehistory, maritime activity, coastal activity and aviation can all occur below ground level, at ground level, and upstanding. Coastal zones have been demonstrated repeatedly to have high potential for the presence of heritage assets.
This is partly because of the range and density of past human activity in today's coastal zones and partly because, despite the high energy of these environments, coastal zones often preserve archaeological material – notably organic materials – that do not survive in dry land contexts. The presence of a very wide variety of heritage assets in 'Close to Shore' and 'Crossing Shoreline' environments also contributes to the richness and complexity of the historic character of the landscapes and seascapes that may be affected by tidal range developments.

As explained in Section 3.2.2, the economic viability for a tidal range development (based on present technology) requires locations where there is a large tidal range (MTR > 4m) in either semi-enclosed or shallow areas that will enable the construction of impoundment walls. These same factors mean that sites of interest are likely to be associated with extensive intertidal zones. Intertidal zones have been a focus for relatively intense human activity over the millennia because they provide access to a wide range of natural resources as well as to transport and communication.

Today's intertidal zones also include areas of low-lying land favoured in prehistory that were more distant from the sea when occupied, but which have since come within the range of the tides as a result of sea level rise since the last glaciation. Prehistoric sites now in intertidal areas provide insights that are not as easily obtained on today's dry land either because the original activity had a coastal dimension, or because of the quality of preservation of organic artefacts that would have entirely decayed if they had not remained waterlogged. The themes of submerged prehistory and coastal activity often overlap in the intertidal zone, resulting in complex palimpsests where heritage assets that are in close proximity today are from widely different periods and environmental contexts.

In addition to sensitive intertidal zones, the 'Crossing Shoreline' environment also encompasses the fringe of coastal land above high water but nonetheless heavily influenced by the sea. As with the intertidal zone, today's fringe of coastal land may not reflect the environment represented by archaeological remains in this margin. There could have been extensive erosion, such that archaeological remains on the shoreline relate to former terrestrial sites; or there might have been extensive reclamation with shoreline embankments protecting extensive coastal 'land' in which former marine and intertidal deposits now lie. This coastal fringe can be very diverse and highly significant in archaeological terms, including heritage assets atop hard cliffs, amongst dunes or in low lying saltmarsh. Even in the absence of development, coastal land is a matter of intense concern for heritage management because of the complex issues such as erosion and changes to hydrology associated with rising sea-levels and increased storminess.

Maritime activity – boats, ships and related infrastructure such as hards, harbour walls, jetties, slipways and so on – occur in 'Close to Shore' and 'Crossing Shoreline' environments either by design or by accident. Infrastructure for enabling ships and boats to make contact with the shore often survives at former landing sites, which are often more numerous than today's ports and harbours. Although landing sites are generally small in scale, reflecting finer-grained networks of maritime activity in the past, in some cases there are fairly major harbour works that have been abandoned, especially if originally associated with an industry that collapsed. Other than when landing, boats and ships generally avoid shallow areas close to the coast; but all manner of incidents can lead to wrecking, and to the presence of very significant shipwreck remains in nearshore and intertidal environments. Historically, boats and ships have also been intentionally discarded ('hulked') in nearshore and intertidal environments, providing a further class of heritage asset likely to be encountered in areas favoured for tidal range development.

Submerged prehistory, coastal activity and maritime activity encompass time periods that are very long. Prehistoric remains in intertidal areas in England are in fact some of the earliest traces of human activity in North West Europe, dating back almost a million years (Ashton *et al*, 2014). Prehistoric flint artefacts that are several hundred thousand years old are being routinely recovered from the seabed of the UK Marine Area (Tizzard, Bicket, and De Lococker, 2015). For 'Close to Shore' and 'Crossing the Shoreline', submerged prehistory, coastal activity and maritime activity is commonly encountered that encompasses several millennia from the Bronze Age to the Modern period; military heritage assets are also often widespread.

Heritage assets associated with aviation in 'Close to Shore' and 'Crossing the Shoreline' environments are also usually military in character, and generally accidental in origin. Aircraft crash sites are increasingly recognised as a consideration in coastal and marine environments, and they are automatically protected under the Protection of Military Remains Act 1986. Seaplane bases and their infrastructure may also occur in 'Crossing the Shoreline' environments, dating back not only to the flying boats of the Second World War but also to seaplanes that were heavily used in the First World War to combat U-boats.

As indicated, the morphology and character of 'Close to Shore' and 'Crossing the Shoreline' environments may have changed significantly since the time at which heritage assets were originally constructed or deposited. Prehistoric material on the shoreline may date to periods when the coast was many kilometres distant. In more recent millennia, reclamation for agriculture, or in urban and industrial settings, may have altered the coastal zone very significantly. Natural processes will also play a major role in the appearance of heritage assets at the coast, resulting in archaeological material being periodically buried or exposed in subtidal and intertidal areas, and the fringe of coastal land.

An example of the dynamic character of the seabed was recently reported from routine surveys undertaken by Bristol Port Company in the Severn Estuary, where their survey of Welsh Hook in 2017 revealed a substantial shipwreck that was previously uncharted (Figure 20).

Historic England has suggested that the most likely candidate for this wreck is the English cargo vessel SS *Brunswick* which got stranded on the Welsh Hook on Christmas Eve 1900 (Current Archaeology, 2017). The location of this wreck, as well as the dynamic character of the seabed, is directly relevant to tidal range development in the Severn Estuary which may have implications on seabed morphology (for example the occurrence and movement of sedimentary bedforms, such as sandwaves and sandbanks).

In other circumstances, the combination of sediment supply, along with a reduction in exposure to wave and tidal energy, may cause deposition, such that archaeological material is not visible but no less present. Even in environments where the 'Crossing the Shoreline' environment comprises exposed rock on the seabed, as a wave cut platform or in a cliff, attention should be paid to the possibility of rock-cut features, to archaeological material preserved in gullies, and to clifftop heritage assets.

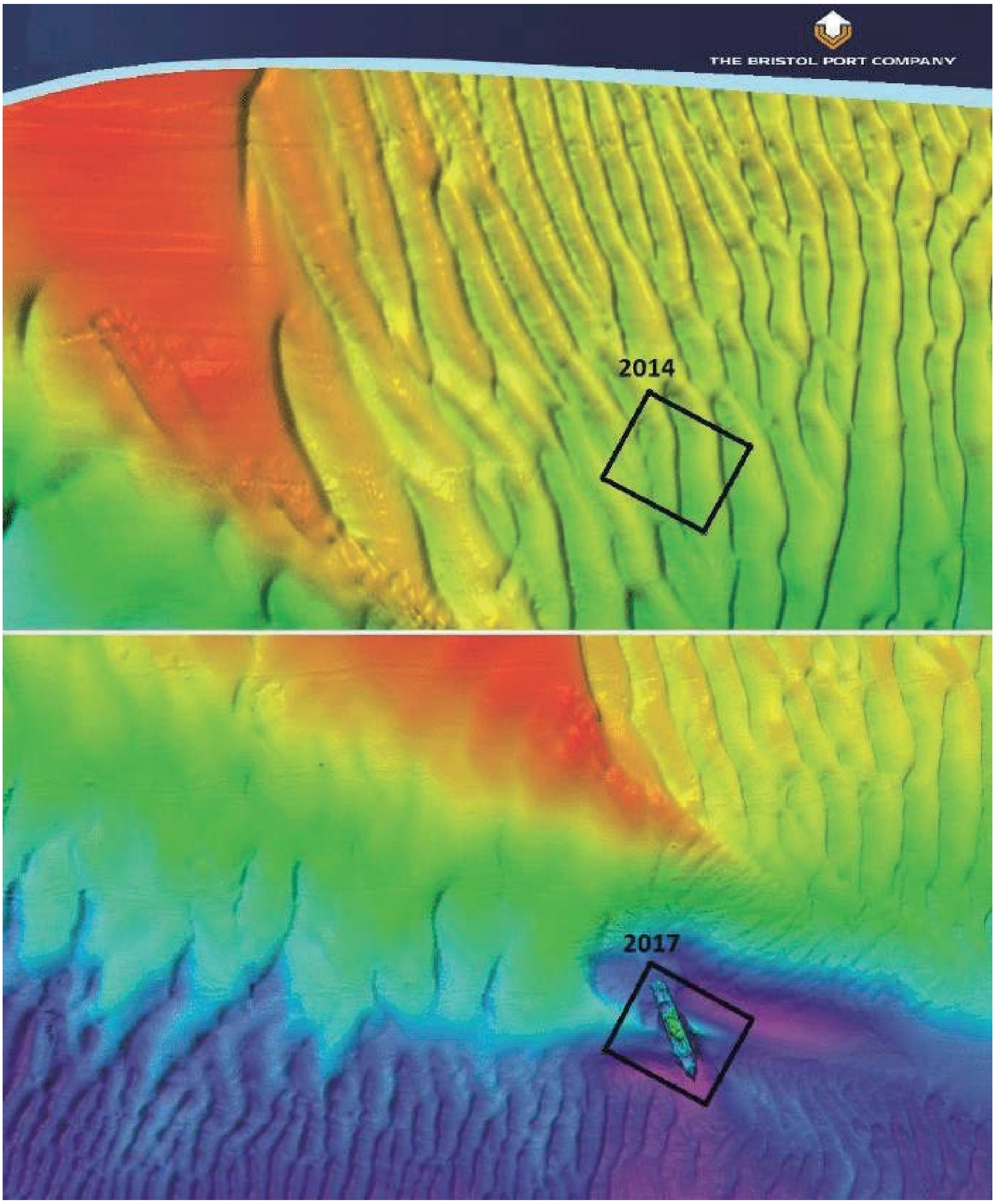

Fig 20 Surveys of Welsh Hook, Middle Grounds sandbank (Image: The Bristol Port Company).

6.2 Potential impacts of Tidal Range Developments on Heritage Assets

The scope of the present research does not allow for any project-specific consideration of environmental impacts on the historic environment, nor would that be possible for most projects at this stage in their development. The requirement for scheme-specific assessment will need to be fulfilled by each developer in consultation with Historic England as part of the consenting process and according to relevant guidance available at that time. Instead some high-level general comment is offered to help ensure such considerations are factored into any upcoming environmental assessment work.

Impacts from tidal range development could arise from the following four phases of development that were outlined in Section 2.5: pre-construction, construction, operation and decommissioning.

In the pre-construction phase, intrusive site investigations may occur to help support an application for consent, or as part of detailed design and preparation between consent being granted and construction commencing. Although intrusive site investigations can be damaging to heritage assets, such work (as well as non-intrusive site investigations) often provide opportunities to better understand the presence of and potential for heritage assets. Planning for site investigations needs to include historic environment advice to avoid inadvertent impacts but also to make the most of the opportunity to better inform subsequent phases of work.

Decommissioning is likely to focus on areas of a scheme where physical impacts occurred in the construction phase; the additional impacts on the of decommissioning relative to construction may not be great. Hendry has indicated that major structures should be regarded as permanent and not be subject to decommissioning (Hendry, 2016), so operational effects on heritage assets, including on their setting, will continue. However, what is worth bearing in mind is that tidal range schemes may themselves contribute to the historic environment over the timescale of their use (potentially > 100 years) and may come to be regarded as heritage assets in their own right – as has occurred with a range of major twentieth century industrial and engineering projects.

Potential impacts in the construction and operational phases will be of greatest concern. Broadly, construction phase impacts will arise in respect of immediate physical changes to heritage assets within the footprint of the works; operational phase impacts will arise from changes to the environment caused by the scheme both within the impoundment and in the area influenced by changes to marine and coastal processes beyond the scheme. Operational phase impacts will also include effects on the setting of heritage assets in the region within which the scheme is visible, and on the historic character of the landscape/seascape.

In view of the differences between different phases and different zones, the following discussion is organised according to the zones described in Section 2.4, that is:

- Construction footprint
- In proximity to power houses and sluices
- Within the impoundment
- Beyond Impoundment

6.2.1. Construction footprint

Impounding walls are the largest construction elements of the schemes considered in this study; typically, they are many kilometres in length. In the main, they will abut coastal land, cross intertidal zones and extend over fully subtidal areas. The width of their footprint will depend on the form of construction: the width of vertical walls may be limited but if sloped (to absorb wave energy) then the overall width may be considerable, especially in deeper water. The anticipated width of the impoundment wall for Swansea Bay Tidal Lagoon, for example, varies from 40 to 100m (Tidal Lagoon Swansea Bay, n.d.). Any heritage assets that are upstanding or at bed level within the footprint of impounding walls will be destroyed by construction; any buried heritage assets are likely to be seriously compromised and future access to those assets will be precluded. Piling for foundations or dredging to prepare the ground will add to the impact on heritage assets. As well as the footprint of the wall itself, heritage assets in its vicinity may be affected by construction activities such as anchoring and spudding-in by jack-ups.

The scale of impounding walls is such that their construction materials are likely to be brought in by sea, but there may still be a requirement for access roads and construction compounds on land. Equally, permanent constructions such as car parks and amenity buildings may be built to accompany the scheme if visitor and recreation facilities form part of the overall design. Such facilities, especially if extensive and in ‘green field’ areas, can amount to sizable schemes in their own right as far as heritage assets within their footprint on land are concerned.

Where materials and equipment are brought in by sea, navigation routes and mooring zones may be required. In some instances, additional dredging may be required to enable access by sea. Additional dredging may also be required to win material for use in the walls, as proposed at Swansea Bay. Any other dredging to increase overall volume, to provide general levelling or to enhance the scheme is best regarded as part of the construction footprint even if it is not related to any structures and their foundations. Any heritage assets within the horizontal and vertical footprint of dredging will be destroyed.

In areas where mooring by construction vessels is encouraged, there is potential for impacts from anchors, mooring chains and jack-up spuds. The size of construction vessels is such that the area impacted by anchors, chains and spuds can be considerable and, depending on ground conditions, the impacts can penetrate deeply into sediments.

The power house for a tidal range development is the structure within which the turbines are located. Power houses are large structures that, as highlighted above, need to have sufficient depth to avoid the turbines experiencing cavitation. Dredging may be required both to achieve sufficient depth for the power house, but also to form stable surrounding slopes. Power houses are themselves large structures; as noted previously, the structure planned for Swansea Bay is 410m long, 67.5m wide and is submerged by around 14m (high) Chart Datum. In addition to dredging, construction of the power house may be accompanied by temporary piling for a cofferdam (as at Swansea Bay) or permanent piling and ancillary works to provide a solid foundation and/or protection against erosion. As with impounding walls, heritage assets are likely to be destroyed if they are within the immediate footprint of the power house, of associated dredging and ancillary works, or in the margin around the power house used for construction (including anchoring, spudding in and any temporary works). Construction phase impacts will encompass heritage assets that are upstanding, at bed level or buried. A case may be made that heritage assets that are below the level of construction/dredging/piling will not be destroyed, but access to them in future will certainly be impeded.

Other major construction works may be required for structures to house sluices or for locks that can enable vessels to pass in and out of the impoundment. The impacts from construction, dredging, piling and so forth., both within the footprint of the structure and its vicinity, will be similar to those for the construction of turbine house.

Other impacts associated with construction are sediment plumes created near the works due to seabed disturbance as well as the need to dispose of surplus arising at licensed spoil sites. The sediment plumes might affect underwater visibility for a short period and access to marine heritage assets, and potentially result in masking by fine sediment.

During the operational phase, the effects of impounding walls and related structures on heritage assets in their immediate vicinity are unlikely to be great, especially relative to those during the construction phase. Impounding walls will have been designed and built to avoid causing secondary effects in their vicinity such as scour (erosion). However, if an impounding wall encouraged local scouring, then heritage assets within the footprint of the scour will be at risk of being destroyed. Monitoring of scour development around fixed structures in the operational phase should make provision for identifying and responding to such risks.

6.2.2. In proximity to power houses

The purpose of impounding the tide is to store energy that can be released through the power house for generation of electricity. During periods of draining and filling the direction and strength of flows in this area will become highly modified from baseline conditions with the extent of such modification likely to be greater than the footprint of any construction related dredging in the immediate vicinity of the power house. The area affected will be both outside the impounding basin as well as inside.

Although there may not have been any construction phase impacts on heritage assets in the area beyond the power house, some effects may occur in the operational phase. Changes to flows may have effects on sediment transport. For heritage assets at and above bed level, increased current velocity may result in permanent removal of coverings of fine-grained sediments (exposure) and potentially even erosion of consolidated deposits, which could also compromise heritage assets that are buried. Decreases in current velocity may cause deposition, which is advantageous to heritage assets, in principle, because this process generally reduces damaging physical, chemical and biological processes; but deposition may also mask such assets from archaeological investigation and/or visitors.

Upstanding heritage assets such as wrecks often have complex patterns of scour and accretion around them – sometimes over distances many times the size of the wreck – reflecting the established influence on sediment transport of tidal currents as they ebb and flow. If tidal currents are changed by impoundment, then the pattern of scour and accretion is also likely to change. As above, accretion in new areas is, in principle, a benefit though some features may become masked. Changes to scouring, however, could amount to erosion of areas that were previously buried; such scouring is likely to cause the heritage asset to deteriorate. The implications of changing tidal flows for heritage assets in proximity of power houses will warrant specific attention when assessing impacts in the operational phase.

Increased currents in proximity to power houses may affect access to heritage assets (for example by diving) over a wider area than any safety considerations relating to the turbines themselves.

6.2.3. Within the impoundment

Substantial changes to flows are unlikely to affect the whole of the impoundment, but there may still be implications for the historic environment that need to be taken into account across the whole scheme. Impoundment is intended to create a 'head' between the normal level of the tide and the impounded water, either on the ebb, the flood, or both. The interruption of the tidal cycle will mean that high water and low water will be different, in level and/or timing, to the baseline condition.

As noted above, the tidal range within the impoundment tends to be slightly reduced, with a lower high water and a higher low water. This may have implications for the condition and survival of organic archaeological material that is above the new high water but below the old high water, because this area will be dry more often than previously. However, this is a complex matter to consider because material in the intertidal zone is always subject to wetting and drying, not only daily but also due to the spring-neap cycle and longer cycles (for example equinoctial tides).

Where low tides are not as low as previously, archaeological material below the new low water will not be as accessible to intertidal survey methods. Again, this is a matter of degree because low tide varies in level; but the important opportunity that very low tides provide for intertidal fieldwork may be lost.

Generally, the timing of intertidal surveys within tidal impoundments will have to be recalibrated to the artificial cycle.

A major change within impoundments is the reduction of fetch, which is the length of water over which wind can generate waves. The impounding wall will protect the area within the impoundment from swell waves and limit the distance over which wind waves can form before reaching the shoreline. This is likely to result in a marked reduction in wave energy reaching the shore, which could be beneficial to heritage assets at risk from coastal erosion both in intertidal areas and within coastal land fringing the impoundment. However, the reduction in energy is also likely to have other effects on sediment transport, potentially causing deposition and masking of features both in intertidal and sub-tidal areas. Masking effects across the impoundment, as a whole, may be exacerbated by changes in the overall budget of sediment flowing into and out of the impoundment basin following construction.

Depending on the regulatory framework adopted within the impoundment, there may be restrictions on diving, boat access and the ability to conduct for example marine geophysical investigations, all of which will affect people's ability to investigate or visit heritage assets.

6.2.4. Beyond the impoundment

Impacts can also be anticipated outside the impoundment, beyond the immediate influence of the power house, sluices and other infrastructure. Changes to current flows and directions, waves activity and sediment transport pathways can be expected to have effects on deposition and erosion of sediments that will affect the condition and visibility of heritage assets that are upstanding or at bed level. Such changes may also have effects on intertidal areas and on the fringe of coastal land above high water, which have been flagged above as encompassing significant archaeological material that is already under pressure from the consequences of climate change.

As is the case inside the impoundment, established patterns of scour and accretion around wrecks and other heritage assets may change, whether they be fully submerged, in intertidal areas, or at high water. Patterns of scour and accretion around heritage assets identified in the general area may in fact serve as useful proxy for the extent and magnitude of changes to the marine environment caused by tidal range developments.

Changes to the marine environment much further afield, which might have implications for heritage assets, may also occur as a result of the in-combination effects of a programme of tidal lagoon construction, or of the combination of tidal lagoons and other major marine developments. Areas with estuaries and high tidal ranges are complex environments and, as noted above, they also have high potential for the presence of a very wide range of heritage assets. Consideration of in-combination effects must also give due consideration to possible effects on the coastal and marine historic environment.

The most obvious impact of tidal range developments on heritage assets many kilometres from a scheme will be on the physical setting and the broader character of the landscape/seascape. Impounding walls are typically very long whilst power houses, sluices and related infrastructure are large buildings in themselves. At high tide, the structures may only appear to be a few metres high, but for most of the tidal cycle they will be much more prominent. As tidal range developments tend to be economically viable for sites with a mean tidal range of greater than 4m, but preferable where the range is significantly more (Swansea Bay has a mean tidal range of 6.58m and a maximum range of 10.5m), then the appearance of the impounding wall and power house will be equivalent to a building several storeys in height. As noted above, the influence of the impounding walls on reducing fetches and providing local sheltering will also mean that the sea state within the impoundment is different to outside in most weather conditions, which will also add to the change in visual appearance.

The impoundment infrastructure and basin are likely to amount to a substantial change to the setting of heritage assets in the area. Where the heritage asset has a relationship to the sea – such as a maritime building, coastal defence installation, seaside Conservation Area, or a designed landscape that references maritime views – then the change in setting is likely to affect the significance of the heritage asset. The changes that accompany a tidal range scheme may also have a broader effect on the landscape/seascape including aspects of its character that afford historic significance. The precise character of the effect on significance will need specific attention. Some sense of the scale and character of effect might be obtained from structures such as the harbour walls at Dover (overall length including entrances *c* 3.8km) and Portland (overall length including entrances *c* 5.75km), though the schemes under consideration are typically longer. A point worth bearing in mind is that the harbour walls at Dover and Portland are themselves now designated heritage assets and have a setting of their own and contribute to the historic character of the landscape/seascape of those ports. The potential remains that the main structures of a tidal range development could similarly become recognised for their special architectural or historic interest, and for their contribution to the character of the landscape/seascape, in the fullness of time.

6.3 Potential impacts of compensation schemes

Compensation schemes are intended to reintroduce tidal conditions to areas of land protected by embankments and are often accompanied by other measures to enhance the nature conservation value of the compensation site. These embanked areas are usually places that have been reclaimed and protected for agricultural purposes. The most recent embankments may appear to have been built or maintained in recent centuries, but these areas often have very complex histories of human use; the original reclamation may be Medieval or earlier in date, and the area is likely to have been used prior to reclamation in its former tidal condition. There may be evidence of even earlier use as a freshwater-dominated landscape when sea levels were lower.

Although compensation schemes comprise the reintroduction of natural processes, this does not mean that the scheme is itself natural. Compensation schemes generally involve a degree of intrusive work that may impact heritage assets. As well as breaching the embankment (which may be a historic feature), various bunds, ditches, borrow pits and habitats are likely to be constructed, which will entail stripping the ground surface, excavation, access routes and compounds, vehicle tracking and so on. In addition to direct works, compensation is intended to enable processes to take place that will further change the environment, such as the erosion of tidal channels not only within the compensation site but across the foreshore. Wider changes are also likely to occur in water levels and water quality, with the introduction of seawater, which may affect the condition of heritage assets that remain below ground.

Several instances of compensation schemes have demonstrated very extensive impacts on heritage assets that have necessitated major programmes of mitigation and monitoring funded by the developer or scheme promoter. Examples include London Gateway Stanford Wharf (Biddulph, Foreman, and Stafford, 2012), Steart Point (Higbee and Mepham, 2017), and Medmerry (Krawiec, 2017). The programmes of archaeological work necessary to assess, evaluate and mitigate the impacts of compensation at these sites required multiple phases of investigation and involved considerable input of programme time and resources. Archaeological considerations are likely to be a major concern at most sites flagged as compensation sites and adequate time and funding must be factored in to the scheme by the developer/promoter. Early consultation with curatorial authorities is essential.

7. CONCLUSIONS AND RECOMMENDATIONS

A review has been produced of publicly known tidal range development activity likely to affect English Waters.

Four regions have been identified where the technical resource presents economic viability for development of tidal range schemes; Eastern Irish Sea, Bristol Channel, Eastern English Channel, and The Wash and Humber Estuary regions.

A total of 17 projects have been identified across these regions which are either wholly or partly in English Waters, and further 4 schemes considered in close enough proximity to have some influence in English Waters. The Swansea Bay Tidal Lagoon is included in the review only as an illustration of a first pathfinder project, but this project is not considered to lead to any concerns for Historic England.

The requirements for compensatory measures (that is type of measure, amount of areas required and the location of sites) from any of these schemes remains unknown at this time, but these measures are likely to have equivalent scales to the areas impounded, as a guide. Ideally, these sites need to be away from any influence from tidal range developments.

The Eastern Irish Sea region is shown to have the greatest level of present interest; most projects with the greatest total installed capacity, however, the larger set of schemes are located in the Bristol Channel which also has the greatest focus of tidal lagoon options.

In contrast, there appears to be much less interest in developing projects in the Eastern English Channel or in The Wash and Humber regions, largely explained by the reduced amount of technical resource (smaller areas and lower tidal range).

Most projects appear to be at the feasibility stage, with only the Swansea Bay Tidal Lagoon achieving a consent.

Most projects also appear to be dormant at this time, with developers seeking clarity on the Government's position on the Hendry Review and requiring further investment to move into detailed studies to demonstrate their effects on the environment and their requirements to offset any habitat losses with suitable compensatory measures.

Detailed studies may identify further environmental constraints (for example site investigations revealing heritage assets) and requirements for design modification which may include the general layouts in some cases. Barrage layouts are likely to be less flexible than lagoon options.

Requirements for compensatory measures are only likely to emerge through detailed EIA studies and in consultation with statutory nature conservation bodies. However, the effects from a tidal range development are likely to be large and the associated compensatory measures similarly large. The relevance of heritage assets applies equally to compensation sites as well as tidal range development sites.

Not all the projects identified in this review are expected to become operational, noting also that some of the sites of interest have multiple projects where perhaps there is only the capacity for a single scheme.

The present mechanism for consenting large NSIP projects ensures engagement and participation of interested parties prior to application, for example Section 42 consultation exercise on a Preliminary Environmental Information Report. Early engagement in this process will provide a greater chance for influencing the development. Smaller projects will still require an EIA and a consultation process with relevant stakeholders.

The Government's position on tidal range developments remains unclear at this time with a response to the Hendry Review still expected in due course. The BrExit process also adds to the uncertainty, with implications to the legislative and consenting process.

Subject to the Government's response to the Hendry Review, there is potential for a new NPS that identifies sites selected for development, for further activity to examine the implications of a programme of tidal range development through SEA, for the emergence of a Tidal Power Authority, and for changes to environmental legislation. Historic England should ensure their advice informs all of these potential upcoming issues.

Tidal range developments have the potential to affect heritage assets relating to each of the main themes of coastal and marine archaeology in a variety of environments: on land; crossing the shoreline; and close to shore.

Different effects on the historic environment are likely in the different phases of development and in the different zones associated with each development. Although attention might focus on construction phase impacts in the immediate footprint of the impounding walls, power house and other infrastructure, consideration also needs to be given to operational phase effects in proximity to the power house where tidal currents are increased, within the impoundment and beyond the impoundment.

Impoundment walls and power houses are likely to be large structures which, taking account also to the change in the character of water within the impoundment, could have effects on the settings of heritage assets well beyond the development. Hendry recommends that impoundment walls be regarded as permanent. The possibility exists that the structures associated with tidal development may come to be regarded as heritage assets during their operational phase, as has occurred with other major marine works that are now designated.

There may be operational effects from tidal range development on the investigation of heritage assets and on the ability of the public to see or visit heritage assets. The emergence of a programme of large scale tidal range developments is likely to require better understanding of the implications for accretion and scouring around wrecks, and masking of intertidal sites, including for heritage assets beyond the impoundment.

Previous examples suggest that compensation sites are likely to contain a wide range of heritage assets warranting extensive investigation and mitigation. Archaeological considerations are likely to be a major concern and adequate time and funding must be factored into their design.

The following recommendations are offered to Historic England:

- Consider in detail the Government's eventual response to the Hendry Review to establish what

- further actions Historic England ought to take with respect to tidal range developments.

- If Government plans to support a strategic programme of tidal range developments and clarify this with a new NPS, then Historic England should ensure their advice informs this effort.

- Stay abreast of proposals for tidal range development that may emerge before the Government's response, including 'small scale' developments that are below the threshold of an overall programme (that is non-NSIP).

- Maintain awareness of projects in adjacent territorial waters which may have effects translating into English Waters, including identifying compensatory measures for heritage assets in English Waters, even where the project is situated in another home country.

- For non-NSIP energy generation projects, produce guidance for developers of tidal range developments, including the importance of assessing compensation sites as a topic.

- Seek early engagement with developers during consultation on the direct footprint of the development structures (lengths, widths and depths), plus any extended footprints and dredging requirements during construction, as well as any export cable routes. This point is especially important where design information is likely to evolve as work progresses and various design iterations can be expected to both mitigate and optimise the development.

- Carry out strategic research on possible changes to waves and tides within and beyond impoundments and their associated impacts on erosion and accretion near heritage assets to inform advice to developers on the scope of project-specific assessments.

- Specifically address the considerations for the historic environment of compensation schemes in conjunction with other forms of other large-scale shoreline intervention that could have in- combination and cumulative effects, especially in the Severn Estuary/Bristol Channel and areas such as the East Coast away from the attention likely to be focussed on tidal range developments.

- Engage with OESEA3 to help influence programmes of work relevant to the historic environment for both regions of development and regions for compensatory measures.

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